THIS NUMBER COMPLETES VOLUME III

VOLUME III NOVEMBER, 1920 NUMBER 6

JOURNAL OF DAIRY SCIENCE

OFFICIAL ORGAN OF THE
AMERICAN DAIRY SCIENCE ASSOCIATION

J. H. FRANDSEN, Editor-in-Chief
Lincoln, Nebraska

BOARD OF EDITORS

A. C. ANDERSON, Lansing, Mich.
F. W. BOUSKA, Chicago, Ill.
C. H. ECKLES, St. Paul, Minn.
E. S. GUTHRIE, Ithaca, N. Y.
H. A. HARDING, Urbana, Ill.
O. F. HUNZIKER, Chicago, Ill.
H. H. KILDEE, Ames, Iowa
C. LARSEN, Brookings, S. D.
C. W. LARSON, Dairy Div. Dept. Agri., Washington, D. C.
W. B. P. LOCKWOOD, Amherst, Mass.
M. MORTENSEN, Ames, Iowa
LEROY S. PALMER, Columbia, Mo.
FRED. RASMUSSEN, State College, Pa.
B. H. RAWL, Washington, D. C.
C. L. ROADHOUSE, Davis, Calif.
L. A. ROGERS, Washington, D. C.
W. A. STOCKING, JR., Ithaca, N. Y.
M. R. TOLSTRUP, Henderson, Minn.
H. E. VAN NORMAN, Davis, Calif.
R. M. WASHBURN, St. Paul, Minn.
IVAN C. WELD, Washington, D. C.
G. C. WHITE, Storrs, Conn.
W. B. NEVENS, Lincoln, Nebr.

CONTENTS

Proportioning the Ingredients for Ice Cream and Other Frozen Products (The Balance Method). O. E. WILLIAMS 439
A Study of the Incorporation of Proteins in Creamery Butter. R. W. WYANT 452
Factors Influencing the Viscosity of Sweetened Condensed Milk. L. A. ROGERS, E. F. DEYSHER AND F. R. EVANS 468
Bitterness in Evaporated Milk. GEORGE SPITZER AND W. F. EPPLE 486
The Effect of Pasteurization on the Number of Bacteria in Milk When This is Determined by the Direct Microscopic Count. E. G. HASTINGS AND AUDREY DAVENPORT 494
Is Ropy Milk Becoming a More Serious Dairy Trouble? H. A. HARDING AND M. J. PRUCHA 502
A Comparison of the Butterfat Content and the Total Solids Content of Creams of Varying Richness Separated from the Same Sample of Milk. B. A. STIRITZ AND O. R. OVERMAN 522
A Study in Bulls. ANDREW C. MCCANDLISH AND LAURENCE M. WINTERS 529
Bacterial Control in Milk Plants. RUSSELL S. SMITH 540
Abstracts and Review of Dairy Literature. H. A. HARDING 555
Dairy Notes. J. W. HENDRICKSON 556
Index 561

PUBLISHED BI-MONTHLY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter June 9, 1917, at the Postoffice at Baltimore, Md., under the Act of March 3, 1879
Acceptance for mailing at special rate of postage provided for in Section 1103,
Act of October 3, 1917, authorized on July 16, 1918

Copyright 1920 by Williams & Wilkins Company

Price net postpaid per volume { $5.00 United States, Mexico, Cuba
$5.25 Canada
$5.50 Other countries

DIFCO

BACTO-PEPTONE

The Original Standardized Peptone for Bacteriology. No other Peptone is so uniform in its Chemical and Biological Constants

PREPARED from basic materials carefully selected and assayed.

PROCESSED under scientific methods of factory control.

STANDARDIZED by precise chemical and bacteriological tests.

ADJUSTED to give a definite H-ion concentration in solution.

INDOL REACTION assured by a constant tryptophane factor, and gauged to a positive indication in twenty-four hours.

NITROGEN content never less than 15.2% in the form of molecules ideally adapted for bacterial nutrition.

ANTITOXIN made from Bacto-Peptone by purveyors to the U. S. Military establishment and to foreign Governments.

MENTIONED favorably in current scientific literature by disinterested authorities.

IN USE all over the world.

Bacto-Peptone stands on its own merits and completely substantiates all claims made for it

Carried in Stock by the principal Dealers in Scientific Supplies

DIGESTIVE FERMENTS COMPANY,

DETROIT, MICHIGAN, U. S. A.

The Margin of Safety

The need of a "margin of safety" is not confined to the building of bridges or sky scrapers.

Milk and milk products need the "safety margin" which efficient and dependable cleanliness provides.

The growing use by the dairy industry of

Wyandotte
Dairyman's
Cleaner and Cleanser

is contributing very largely to the protection of the dairy, creamery and cheese factory from the preventable losses which result from unsanitary conditions in manufacturing processes.

Then, too, they say that this cleaner supplies this adequate protection very economically.

Order from your supply house.

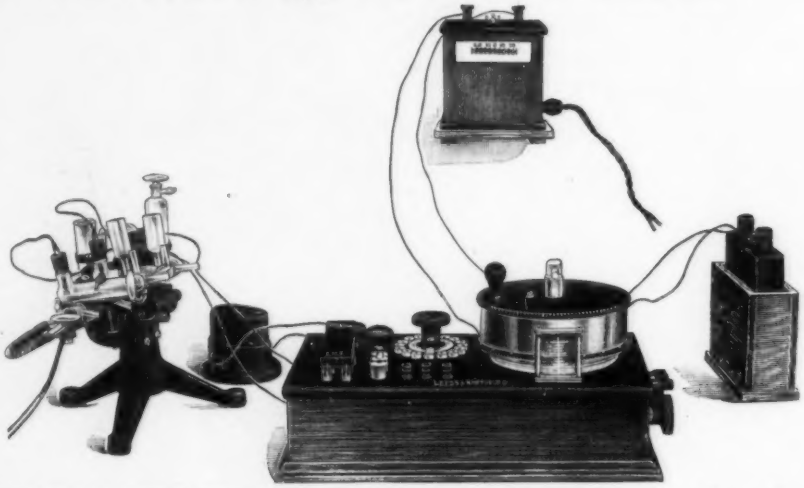
Indian in circle

in every package.

It cleans clean

The J. B. Ford Co., Sole Mnfrs., Wyandotte, Mich.

Satisfaction of the User is Convincing Proof of Merit



TYPE K POTENTIOMETER OUTFIT *as used in pH measurements, with two Clark type of hydrogen electrodes and accessory glassware mounted on motor-driven shaking device. See Chapters XI and XII of Clark's "The Determination of Hydrogen Ions."*

The uniformly successful and satisfactory operation of the Type K Potentiometer with its accessories for Hydrogen Ion Measurements has made it a valued and important part of the equipment of many laboratories carrying on scientific investigations or controlling production processes.

"Electrometric Methods and Apparatus for Determining Hydrogen Ion Concentrations"—Leeds & Northrup Catalogue 75D—will help you determine whether the Type K Outfit is adapted to your work, or whether some other combination of instruments would serve as well.

If your work leads you into problems of acidity or alkalinity determinations, or of making accurate titrations under difficult conditions, reading of Catalogue 75D may represent time well spent. We shall be glad to furnish the catalogue.

LEEDS & NORTHRUP COMPANY

Electrical Measuring Instruments

4901 Stenton Avenue Philadelphia, Pa.

Quick Sterilization of Dairy Utensils

There is a quick, easy, economical way to sterilize milking machines, pails, cans, bottles, vats, separators, strainers, and all receptacles used in the handling and shipping of milk. That way is by using Fecto, a standardized solution of hypochlorites and chlorine.

Fecto contains about 4% of available chlorine and is ten to twelve times as effective as carbolic acid as a germicide. It is clean, colorless, and non-poisonous when properly diluted. It removes odors and quickly destroys bacteria that produce ropy growths, impart "off" flavors, and lower the quality of milk.

Fecto is supplied in quarter-pint bottles, pint bottles, gallon bottles, and five-gallon containers.

Send for folder entitled "Healthier Livestock and Better Milk."

Parke, Davis & Company

DETROIT

4-ounce and 16-ounce packages supplied in this form

Corroboration is Confirmation

The work of any scientist needs its corroboration—the proof.

CORROBORATION

A new and different way of doing an old job generally is opposed by theorists. If the method is of practical value opposing theories must give way when the user is satisfied.

In the past five years there has appeared considerable information relative to the use of sodium hypochlorite as a sterilizer for dairy and food handling equipment. This has come from the highest of authorities making independent investigations in widely different fields.

The information we have in mind appeared several years after the advent of our superior sodium hypochlorite BK. Our recommendations have been fully corroborated. They were based on accurate, sound, scientific principles in the first place.

These circumstances are significant of the reliability, accuracy, and thoroughness with which the General Laboratories performs its work and of the dependability of its products. To deal with the General Laboratories is to get the benefit of services based on experience and reliability.

You can not fail to admit the value of our recommendations. To assist you to study the question we will gladly send you data, other information and references to show the value of BK for bacteria control in dairy work.

Send for bulletin #320 "Better Milk."

General Laboratories

116 So. Dickinson St. **Madison, Wisconsin**

PROPORTIONING THE INGREDIENTS FOR ICE CREAM AND OTHER FROZEN PRODUCTS (THE BALANCE METHOD)

O. E. WILLIAMS

Dairy Division, Bureau of Animal Industry, United States Department of Agriculture, Washington, D. C.

One of the most satisfactory methods that can be used for proportioning the ingredients in making large ice cream mixes is what we have called "the balance method." It is a method that can be easily understood, is applicable to all combinations of ingredients and reduces to a minimum the chances of error in the calculations. Furthermore it furnishes an itemized record of the ingredients used for each mix. The proportions obtained by this method are based on five conditions:

1. The amount (pounds) of mix that will be necessary to produce the number of gallons of ice cream desired.
2. The composition (standard) of ice cream desired.
3. The amount of solid constituents necessary for the mix.
4. The quantity and physical condition of the ingredients on hand.
5. The composition of the ingredients to be used.

Five examples of this method of proportioning the ingredients are explained as follows:

EXAMPLE I

Mix. Give the proportions for 350 gallons of ice cream testing approximately 14.5 per cent fat, 14 per cent sugar and 6.5 per cent milk solids not fat. The weight of the ice cream desired is 5 pounds per gallon.

Stock on hand. Sugar, 150 pounds of 28 per cent cream, 520 pounds of 43 per cent cream, and skim milk.

Illustration

TOTAL POUNDS DESIRED 1750	INGREDIENTS AND COMPOSITION	COMPOSITION DESIRED		
		Fat 14.5 per cent	Sugar 14 per cent	m. s. n. f. 6.5 per cent
		Constituents necessary		
		253.75 pounds	245 pounds	113.6 pounds
		Constituents furnished		
pounds		*pounds*	*pounds*	*pounds*
245.0	Sugar		245.0	
150.0	Cream, 28 per cent	42.0		10.0
492.5	Cream, 43 per cent	211.75		26.0
862.5	Skim milk, 9 per cent			77.6
1750.0		253.75	245.0	113.6

How to determine the basic conditions

Condition 1. To get the total number of pounds in the mix, multiply the desired number of gallons of ice cream by the number of pounds expected in one gallon of the finished product. For instance, in the first example 5 pounds is the desired weight of one gallon of ice cream, hence:

$$350 \times 5 = 1750 \text{ pounds of mix.}$$

Condition 2. The approximate composition of the ice cream desired in the first example is 14.5 per cent fat, 14 per cent sugar and 6.5 per cent milk solids not fat.

Condition 3. To find the amount of solid constituents necessary, multiply the pounds of mix by the percentage of fat, sugar and milk solids not fat as in the first example:

$$1750 \times 0.145 = 253.75 \text{ pounds of fat}$$
$$1750 \times 0.14 = 245.0 \text{ pounds of sugar}$$
$$1750 \times 0.065 = 113.7 \text{ pounds of milk solids not fat.}$$

Conditions 4 and 5.

Quantity and composition report

	COMPOSITION			QUANTITY ON HAND
	Fat	Sugar	m. s. n. f.	
	per cent	*per cent*	*per cent*	
Cream	28		6.4	150 pounds
Cream	43		5.3	Plenty
Skim milk			9.0	Plenty

After these basic conditions are determined, write the pounds of mix, the percentage of constituents desired and the pounds of each constituent in table form and list the ingredients to be considered for the mix as shown in the illustrations.

Particulars concerning example 1

The calculations necessary in determining the proportions are as follows (consider the ingredients as they are listed):

Sugar. The amount of sugar is the same as the amount calculated for the mix since there is no cane sugar in the other ingredients.

Cream (28 per cent). The 150 pounds of 28 per cent cream does not contain more fat than is needed, hence the entire amount can be used.

Cream (43 per cent). The amount of 43 per cent cream can be determined by subtracting the amount of fat added by the 150 pounds of 28 per cent cream from the total amount required and dividing the remainder by 0.43, thus:

$$253.75 - 42 = 211.75$$
$$211.75 \div 0.43 = 492.5 \text{ pounds of 43 per cent cream.}$$

Skim milk. From this ingredient will come the balance of the constituents (m. s. n. f.) of the mix. The amount required will be the difference between the amount of ingredients already used and the total (1750) pounds required. For instance, $1750 - (245 + 150 + 492.5) = 862.5$ pounds of skim milk.

EXAMPLE 2

Mix. Give the proportions for 500 gallons of ice cream testing approximately 14.5 per cent fat, 13 per cent sugar, 9 per cent milk solids not fat and 0.5 per cent gelatin. The weight of the ice cream desired is 5 pounds per gallon.

Stock on hand. Sugar, gelatin, 342 pounds of 30.5 per cent cream, 1608 pounds of 38 per cent cream, 720 pounds of condensed milk testing 8.2 per cent fat, 42 per cent sugar and 21 per cent milk solids not fat, and skim-milk powder.

Illustration

TOTAL POUNDS 2500	INGREDIENTS AND COMPOSITION	FAT: 14.5% 362.5 LBS.	SUGAR: 13% 325 LBS.	M. S. N. F.: 9% 225 LBS.	GELATIN: 0.5% 12.5 LBS.
pounds		*pounds*	*pounds*	*pounds*	*pounds*
23.0	Granulated sugar		23.0		
12.5	Gelatin (powdered)				12.5
342.0	Cream, 30.5 per cent	104.3		22.0	
524.0	Cream, 38 per cent	199.0		30.0	
720.0	Condensed milk 8.2 per cent fat, 42.0 per cent sugar, 21.0 per cent m. s. n. f.	59.0	302.0	151.0	
23.0	Skim-milk powder			22.0	
855.5	Water				
2500.0		362.3	325.0	225.0	12.5

Particulars concerning example 2

The calculations necessary in determining the proportions are as follows (consider the ingredients as they are listed):

Granulated sugar. The amount of granulated sugar can not be determined until the condensed milk is proportioned.

Gelatin (powder). The amount of gelatin is the same as that calculated for the mix.

Cream (30.5 per cent). The 340 pounds of 30.5 per cent cream does not contain more than a small proportion of the fat required, hence the entire amount can be used.

Cream (38 per cent). The amount of this cream required can not be proportioned until after the condensed milk is proportioned since it contains 8.2 per cent fat.

Condensed milk. The amount of sweetened condensed milk that can be used is limited by the amount of sugar and milk solids not fat it adds to the mix. The 720 pounds of condensed milk will add only 302 pounds of sugar and 151 pounds of milk solids not fat, hence the entire amount can be used.

Granulated sugar. With the condensed milk proportioned, the amount of granulated sugar necessary can be determined by subtracting the amount added in the condensed milk from the total amount required, thus:

$$325 - 302 = 23 \text{ pounds of granulated sugar.}$$

Cream (38 per cent). Now that the condensed milk is proportioned, the amount of 38 per cent cream may also be determined. The amount is obtained by subtracting the sum of the fat contained in the 342 pounds of 30.5 per cent cream and the 720 pounds of 8.2 per cent condensed milk from the total amount required and divide the remainder by 0.38, thus:

$$362.5 - (104.3 + 59.0) = 199$$
$$199.0 \div 0.38 = 524 \text{ pounds of 38 per cent cream.}$$

Skim milk powder. From this ingredient must come the balance of the milk solids not fat needed in the mix. This is determined by the difference between the sum of the m. s. n. f. added by the cream[1] and condensed milk and the total amount required plus 5 per cent.[2] For instance:

$$225 - (22 + 30 + 151) = 22.$$
$$22 + (0.05 \times 22) = 23.1$$

[1] The amount of m. s. n. f. in the cream is determined by multiplying the difference between the amount of cream used and the amount of fat it contains by 0.093 (the amount of m. s. n. f. in the milk serum).

[2] Skim milk powder contains on an average 3.5 per cent moisture and 1.5 per cent fat, consequently an allowance of 5 per cent is made in balancing the m. s. n. f.

Water. The required amount of solid constituents having been added, the amount of water needed will be the difference between the total amount of mix required and the sum of the ingredients used.

The accuracy of the calculations can be ascertained by comparing the sum of the figures in each column with the stipulated amounts placed at the top of each column.

When this is done, the ingredients are proportioned by careful weighing. The mix is then ready to be pasteurized and homogenized.

EXAMPLE 3

Mix. Give the proportions for 350 gallons of frozen product testing approximately 9 per cent fat, 14 per cent sugar, 12 per cent milk solids not fat, and 0.5 per cent gelatin. The weight of the product desired is 5 pounds per gallon.

Stock on hand. Sugar, gelatin, 150 pounds of 28 per cent cream, 480 pounds of 34 per cent cream, skim milk, and 900 pounds of condensed skim milk.

Illustration

TOTAL POUNDS 1750	INGREDIENTS AND COMPOSITION	FAT: 9% 157.6 LBS.	SUGAR: 14% 245 LBS.	M. S. N. F.: 12% 210 LBS.	GELATIN: 0.5% 8.75 LBS.
pounds		*pounds*	*pounds*	*pounds*	*pounds*
245.0	Cane sugar		245		
87.5	Gelatin solution, 10 per cent				8.75
150.0	Cream, 28 per cent	42.0		10.0	
340.0	Cream, 34 per cent	115.6		20.8	
397.0	Skim milk, 9 per cent			35.8	
530.0	Condensed skim milk, 27 per cent			143.0	
1749.5		157.6	245	209.6	8.75

Particulars concerning example 3

The calculations necessary in determining the proportions are as follows (consider the ingredients as they are listed):

Sugar. The amount of sugar is the same as the amount calculated for the mix since there is no cane sugar in the other ingredients.

Gelatin. The amount of gelatin solution is determined by moving the decimal point one place to the left, since the solution is a 10 per cent mixture.

Cream (28 per cent). The 150 pounds of 28 per cent cream does not contain more fat than is needed, hence the entire amount can be used.

Cream (34 per cent). The amount of 34 per cent cream can be determined by subtracting the amount of fat added by the 150 pounds of 28 per cent cream from the total amount required and dividing the remainder by 0.34, thus:

$157.5 - 42 = 115.5$

$115.5 \div 0.34 \times 100 = 340$ pounds of 34 per cent cream.

Skim milk and condensed skim milk. From these two ingredients must come the balance of the constituents (m. s. n. f.) of the mix. To find the proportions subtract the sum of the m. s. n. f. in the cream from the total amount required and divide by 927.5 the difference between the amount of ingredients already used and the total (1750) pounds required.

For instance,

$210 - (10 + 20.8) = 179.2$

$179.2 \div 927.5 \times 100 = 19.3$ per cent solids.

This gives the per cent of solids not fat that the additional 927.5 pounds of mix must contain. To find the proportion of skim milk and condensed skim milk necessary, the "square method" is used.

The calculations for the square method are as follows:

Skim milk 9..... 7 7

19.3

27 ..... 10.3

18.0 total number of parts

927.5 ÷ 18 = 51.53

51.53 × 7.7 = 396.78 pounds of skim milk

51.53 × 10.3 = 530.75 pounds of condensed skim milk

The accuracy of the calculations can be ascertained by comparing the sum of the figures in each column with the stipulated amounts placed at the top of each column.

When this is done the ingredients are proportioned by careful weighing. The mix is then ready to be pasteurized and homogenized.

EXAMPLE 4

Mix. Give the proportions of the following ingredients necessary for 280 gallons of a frozen product testing approximately 10 per cent fat, 8 per cent sugar, and the equivalent of 6 per cent additional sugar in the form of maltose sugar syrup and corn syrup,[3] 10 per cent milk solids not fat, and 0.5 per cent gelatin. The weight of the product desired is 4.5 pounds per gallon.

Stock on hand. Sugar, gelatin, maltose sugar syrup and corn syrup, cream (221 pounds of 40 per cent, 80 pounds of 35 per

Illustration

TOTAL POUNDS DESIRED, 1260	INGREDIENTS AND COMPOSITION	FAT: 10% 126 LBS.	SUGAR: 8% 101 LBS.	M. S. N. F.: 10% 126 LBS.	GELATIN: 0.5% 6.3 LBS.
pounds		*pounds*	*pounds*	*pounds*	*pounds*
	Granulated sugar (cane)				
63.0	Gelatin solution, 10 per cent				6.3
151.0	Syrup, 80 per cent solids				
80.0	Cream, 35 per cent	28.0			
82.0	Cream, 24 per cent	19.6			
78.0	Cream, 29.5 per cent	23.0		28.8	
64.0	Cream, 28 per cent	17.9			
73.0	Cream, 19 per cent	13.8			
59.0	Cream, 40 per cent	23.6			
252.5	Condensed skim milk, 25 per cent m.s. and 40 per cent sugar		101.0	63.0	
35.5	Skim milk powder			34.0	
322.0	Water				
1260.0		125.9	101.0	125.8	6.3

[3] Maltose sugar syrup and corn syrup are only half as sweet as cane sugar; consequently to replace the 6 per cent sugar it is necessary to use 12 per cent syrup. The solids in the syrup weigh about 121 pounds.

cent, 82 pounds of 24 per cent, 78 pounds of 29.5 per cent, 64 pounds of 28 per cent, and 73 pounds of 19 per cent), condensed sweetened skim milk testing 25 per cent m. s. n. f. and 40 per cent sugar, and skim milk powder.

Particulars concerning example 4

The calculations necessary in determining the proportions are as follows (consider the ingredients as they are listed):

Granulated sugar. The amount of granulated sugar can not be determined until the condensed milk is proportioned.

Gelatin. The amount of gelatin solution is determined, as in example 3, by moving the decimal point one place to the left, since the solution is a 10 per cent mixture.

Syrups. The amount of syrup is determined by multiplying 1260 by the percentage desired, thus:

$$1260 \times 0.12 = 151.2 \text{ pounds of syrup.}$$

Cream. Since all the different lots of cream are used except the lot testing 40 per cent, the sum of the first five lots will add 102.3 pounds of fat to the mix and the balance is determined by dividing the difference between 126 pounds and 102.3 pounds by the percentage of fat in the sixth lot, thus:

$$126.0 - (28 + 19.6 + 23 + 17.9 + 13.8) = 23.6$$
$$23.6 \div 0.40 = 59.0 \text{ pounds of 40 per cent cream.}$$

Condensed skim milk. The amount of condensed milk that can be used is limited by the amount of sugar it will add to the mix. Dividing the amount of sugar needed in the mix by the per cent of sugar in the condensed milk will give the amount of condensed milk that can be used, thus:

$$101 \div 0.40 = 252.5 \text{ pounds of condensed skim milk.}$$

Granulated sugar. Since the required amount of sugar is added with the condensed milk, no granulated sugar is needed.

Skim milk powder. The amount of skim milk powder is determined by subtracting the sum of the m. s. n. f. added by

the cream[4] and the condensed milk from the total amount required plus 5 per cent[5] thus:

$$126 - (28.8 + 63) = 34$$
$$34 + (34 \times 0.05) = 35.7$$

Water. The required amount of solid constituents having been added the amount of water needed will be the difference between the total amount of the mix required and the sum of the ingredients used.

The accuracy of the calculations can be ascertained by comparing the sum of the figures in each column with the stipulated amounts placed at the top of each column.

When this has been done the ingredients are proportioned by careful weighing. The mix is then ready to be pasteurized and homogenized.

EXAMPLE 5

Mix. Give the proportions for 220 gallons of a frozen product testing approximately 10 per cent fat, 14 per cent sugar, 10 per cent milk solids not fat, and 0.5 per cent gelatin. The weight of the product desired is 4.5 pounds per gallon.

Stock on hand. Sugar, gelatin, cream 33 per cent, condensed milk testing 10 per cent fat, 22 per cent m. s. n. f. and whole milk testing 3.6 per cent fat.

Illustration

TOTAL POUNDS, 900	INGREDIENTS AND COMPOSITION	FAT: 10 % 99 LBS.	SUGAR: 14.0% 138.5 LBS.	M. S. N. F.: 10% 99 LBS.	GELATIN: 0.5% 4.95 LBS.
pounds		*pounds*	*pounds*	*pounds*	*pounds*
138.5	Sugar		138.5		
49.5	Gelatin solution, 10 per cent				4.95
184.0	Cream, 33 per cent	60.7		44.5	
368.0	Whole milk, 3.6 per cent	13.2			
250.0	Condensed milk, 10 per cent fat, 22 per cent s. n. f.	25.0		55.0	
989.0		98.9	138.5	99.5	4.95

[4] The amount of m. s. n. f. in the cream is determined by multiplying the difference between the amount of cream used and the amount of fat it contains by 0.093.

[5] Skim milk powder contains on an average 3.5 per cent moisture and 1.5 per cent fat, consequently an allowance of 5 per cent is made in balancing the m. s. n. f.

Particulars concerning example 5

The calculations necessary in determining the proportions are as follows (consider the ingredients as they are listed):

Sugar. The amount of sugar is the same as the amount calculated for the mix, since there is no cane sugar in the other ingredients.

Gelatin. The amount of gelatin solution is determined by moving the decimal point one place to the left, since the solution is a 10 per cent mixture.

Cream (33 per cent). The amount of cream can not be proportioned until after the condensed milk is proportioned, since it contains 10 per cent fat.

Whole milk (3.6 per cent.) Temporarily omitted for the same reason.

Condensed milk. The amount of condensed milk necessary in this case is determined by using a rough estimate (see page 451). From this estimate it is found that 250 pounds is about the correct amount, thus:

$$990 - (138.5 + 49.5 + 250) = 552$$
$$552 - (99 - 25.0) = 478$$
$$478 \times 0.093 = 44.5$$
$$44.5 + 55 = 99.5 \text{ pounds of milk solids not fat.}$$

Cream (33 per cent) and whole milk (3.6 per cent). From these two ingredients must come the balance of the constituents (fat and solids not fat) of the mix. To find the amount of each, subtract the amount of fat added by the condensed milk from the total amount required and divide by 552, the difference between the amount of ingredients already used, and the total (990) pounds required, thus:

$$99 - 25 = 74$$
$$74 \div 552 \times 100 = 13.4 \text{ per cent fat in 552 pounds of milk.}$$

This gives the per cent of fat that the additional 552 pounds of mix must contain.

To find the proportions of cream and whole milk that are necessary the "square method" is used.

The calculations for the "square method" are as follows:

33 ..... 9.8
. .
. .
. 13.4 .
. .
. .
. .
3.6 ..... 19.6

29.4 total number of parts

552 ÷ 29.4 = 18.78
18.78 × 9.8 = 184.0 pounds of cream
18.74 × 19.6 = 368 pounds of whole milk

The accuracy of the calculations can be ascertained by comparing the sum of the figures in each column with the stipulated amounts placed at the top of each column.

When this has been done the ingredients are proportioned by careful weighing. The mix is then ready to be pasteurized and homogenized.

ROUGH ESTIMATES

Whenever a mix is made from an unlimited quantity of condensed whole milk the amount of condensed milk required is determined by first making a rough estimate. For instance, in example 5, we do not know what part of the total amount of milk solids not fat of the mix must come from the condensed milk, so we try what we think is about the right amount. In this case the figure taken to begin with was 220 pounds. This figure is taken because from experience we know that about 50 per cent of the m. s. n. f. in the mix must come from the condensed milk. That quantity divided by 22 (the per cent of m. s. n. f. in the condensed milk) shows that it will require about 220 pounds of the condensed milk. This amount would add 24.2 pounds of fat and 48.4 pounds of m. s. n. f. to the mix.

To tell whether or not this is right simply take the difference between the total amount of ingredients already calculated (that is, the pounds of sugar, gelatin, and condensed milk) and the total weight of the mix and subtract the difference between the fat used in the condensed milk and the total amount required to find the amount of milk serum. Then multiply this figure by 9 to get approximately the amount of milk solids not fat that will come from the milk and cream, and the sum of the two will indicate whether the proportions are correct, thus:

$990 - (138.5 + 49.5 + 220) = 542$ pounds of milk and cream
$542 - (99 - 24.2) = 466.0$ pounds of milk serum
$466 \times 0.093 = 43.3$ pounds of m. s. n. f. from serum
$43.3 + 48.4 = 91.7$ pounds of m. s. n. f. in mix.

The total amount of m. s. n. f. lacks about 7 pounds, so we increase the amount of condensed milk 30 pounds, or to 250 pounds, which gives practically the right amount, as shown in the table.

In case the quantity had been increased only by 20 pounds, the figures would show about 3 pounds of m. s. n. f. less than was desired. The amount of milk and cream is then calculated as heretofore explained.

A STUDY OF THE INCORPORATION OF PROTEINS IN CREAMERY BUTTER

R. W. WYANT

Dairy Department, Michigan Agricultural College, East Lansing, Michigan

REASONS FOR MAKING STUDY

For many years creamery buttermakers have been operating upon a single standard for determining the composition of butter. This standard, as established by the Internal Revenue Department, fixed the maximum moisture content of butter below 16 per cent (1). The moisture content was taken as a standard for two reasons: first, because moisture is the least valuable of the butter constituents, and second, the composition of butter, so far as moisture is concerned, is largely under control of the buttermaker. Therefore, a standard which limited the amount of moisture in butter was deemed adequate for the protection of the consumer.

The many supporters of a fat standard regulation maintain, however, that the consumer of butter is paying for the fat which it contains and, therefore, the per cent of fat in butter is of greater importance to the consumer than the per cent of moisture. The logic of the foregoing statement is apparent and without doubt the moisture standard in addition to the fat standard will be finally adopted in all countries where the dairy industry is prominent.

The cost of butterfat has doubled in the past three years. Added to the increased cost of raw material is the constantly increasing overhead expense of operating a creamery. Under these conditions it is obvious that the creamery manager must use all of the legitimate means at his disposal to make the greatest profit from the butterfat which is delivered at the factory. Moreover, competitive conditions compel the operator of a creamery to manufacture butter the composition of which is as near the legal limits as prudence will allow.

The present known methods for determining some of the constituents of butter are inadequate for general creamery practice. The moisture and salt content may be accurately determined in any creamery by the buttermaker. These tests will in the future, as they have in the past, be the ones commonly used in the creamery laboratory. For technical reasons the direct determination of the fat and the protein content of butter must be left to the chemical laboratory.

A recent ruling by Dr. C. L. Alsberg, Chief of the Bureau of Chemistry, has made the double standard effective. This ruling requires that the maximum moisture content of butter be less than 16 per cent and the minimum fat content be at least 80 per cent. The single and the double standards are apparently substantially equivalent and it would seem that so long as adulterants were not used in the manufacturing process, the single or moisture standard would protect the consumer from an inferior or less valuable product.

As evidence of the fact that the single standard and the double standard are not equivalent in so far as the composition of the butter is concerned, the following paragraph is submitted.

In a letter to the members, G. L. McKay, secretary of the American Association of Creamery Butter Manufacturers, reports a conversation with Dr. Alsberg, Chief of the Bureau of Chemistry, in which he states:

> I personally called his attention to the fact that there is at least 25 per cent of the butter now in storage that would be lower than 80 per cent fat, and it would be a serious problem for the dairy business to have his department go out and seize this butter.

Without question this storage butter referred to by Mr. McKay was legal butter as defined under the moisture standard regulation, that is, this butter contained less than 16 per cent moisture. Moreover, this butter represented normal creamery butter manufactured according to modern methods. These facts suggest that the percentage of the constituents of butter other than fat and moisture is of considerable importance.

Butter contains the following commercial constituents: fat moisture, salt, and curd. The fat content and the moisture content are fixed at 80 and 16 per cent respectively. The other constituents of butter must come within the remaining 4 per cent provided the law is not violated or good factory practice abused. A moderately salted butter contains about 3 per cent salt. Some markets prefer a heavier salt while others demand a light salt or none at all. The average salt content of 695 samples of American creamery butter as reported by the Bureau of Animal Industry (2) was 2.15 per cent. This would still leave 1.85 per cent for the curd content. Keeping the other factors constant, 3 per cent salt would leave 1 per cent for curd. This is in agreement with the analyses of the 695 samples mentioned above as the average curd content of this butter was 0.88 per cent. The fact that of the 695 samples of creamery butter analyzed the curd content of individual samples varied from 0.12 per cent to 3.41 per cent makes this problem worthy of study.

All authorities agree that a high curd content should be avoided so as to insure better keeping quality of the butter. For these two reasons this study was undertaken. It was hoped that the extent of incorporation and the factors that are responsible for incorporation might be determined under factory conditions.

REVIEW OF LITERATURE

There is an abundance of published data relating to the composition of creamery butter. The most comprehensive study was completed in 1912 by Thompson, Shaw, and Norton (2) of the Dairy Division and published by the Bureau of Animal Industry. A summary of this bulletin is given on the preceding page. Lee and Barnhart (3) of the Illinois Experiment Station made an extended study of the composition of creamery butter collected from the markets at Chicago, Elgin, and Aurora. These investigators found the average casein and ash content of the 231 samples analyzed to be 0.37 per cent.

Nothing would be gained in this study by reviewing the entire published data upon the composition of creamery butter. Most

of the analyses were made to determine the moisture content as the moisture standard was effective at that time. The curd content of butter has been for the most part ignored. It has been variously reported by investigators as casein, protein, nitrogen, and curd. The per cent of this constituent in butter was often arrived at by subtracting the sum of the percentage of fat, moisture, and salt from one hundred.

Attention might be called to the results of the analyses of 200 samples of Minnesota creamery butter as reported by James Sorensen, State Dairy and Food Commissioner (4), and tabulated by McKay (5). The curd content of this butter, calculated by difference, varied from nothing to 10.42 per cent.

The following review of literature is not by any means exhaustive. The results of the principal investigations upon the relation of curd to the keeping quality and composition of butter are given together with comments by several of the leading authorities.

Guthrie (6) states, "The amount of washing that butter receives and the quality of the wash water is important. From the physical standpoint butter must be washed because the brine should be clear and not milky. From the bacteriological viewpoint the buttermilk should be washed out so that the bacteria will be deprived of it as a food."

According to Jensen (7) "lactic acid bacteria were found to multiply much more rapidly in unwashed than in washed butter."

Thom and Shaw (8) add that "excess curd in butter favors mold growth and if the butter is properly washed it is less subject to the mold."

McKay and Larsen (9) after extended study and observation conclude that "butter should not be over churned in the buttermilk as too much curd and milk sugar are incorporated. This cannot readily be removed and in many instances it injures the flavor and keeping quality of the butter."

McKay and Larsen further discuss the effect of curd upon the keeping quality and composition of butter:

According to the present methods of manufacture, water, salt, and fat are the components most likely to vary. Casein varies very little. Occasionally the curd content may go as high as 4 per cent. It rarely exceeds 2 per cent and seldom falls below 0.5 of 1 per cent. A high curd content will show itself in the butter in the form of a milky brine or in the form of white specks. If there is less than 2 per cent curd present in the butter, the brine shows no noticeable milkiness. More than that much curd can, as a rule, be detected from the color of the brine. If the casein or the curd has been incorporated in the form of small lumps or specks, then abnormal amounts of curd appear. When the sample of butter is taken for analysis such a speck of curd present in the sample raises the final curd content to a comparatively high figure. As has been mentioned before, the curd and milk sugar are incorporated from the buttermilk into the butter during the churning. In manufacturing butter for storage these substances should be excluded from the butter as thoroughly as possible. The milk sugar and albuminoids constitute the chief food for bacterial growth.

Michels (10) believes "one washing in which as much water is used as there was cream is usually sufficient. When butter churns very soft two washings may be advantageous."

Wing (11) advances a reason for the variation in casein content by stating the "higher the temperature at which the cream is churned, the more casein will be incorporated with the butter." Wing concludes without giving any reason that the percentage of casein in butter should not exceed 4 per cent.

Mortensen, Gaessler, and Cooper (12) believe "the pasteurization of sour cream affects the percentage of protein in the butter, as the casein in the presence of the acid is hardened and thrown into clumps known as curd particles that are quite readily removed in the draining and washing of butter."

Stocking (13) concludes "the purpose of washing butter is to remove the buttermilk" without giving any reason either for or against a small amount of curd in the finished butter.

Hunziker (14) concludes:

In the case of the true curd of butter the percentage of curd fluctuates between about 0.5 per cent and one per cent, averaging about from 0.6 to 0.7 per cent, provided that the butter is washed in a normal

manner. Butter made from sweet cream and unsalted butter, has a slightly higher curd content than butter made from ripened cream and butter that was salted. Butter that is only very slightly washed contains more curd than butter in the manufacture of which the churn is stopped when the granules are very small and which is washed very thoroughly. Butter that is not washed at all usually contains from about 1 to 1.5 per cent curd.

THEORETICAL DISCUSSION

The principal nitrogenous compounds of milk are casein and albumin. There are, however, several other proteins in milk studied by Storch (15) which have properties unlike either casein or albumin. These occur in very small amounts and are, therefore, not of great importance commercially. The albumin of milk is in a true solution (16). It likewise occurs in small amounts and is not of commercial importance. The chief nitrogenous compound of milk is the casein. It exists in milk in combination with certain calcium salts in the form of extremely minute gelatinous particles in suspension. Casein is insoluble in water and is precipitated by heat in the presence of dilute acids or acid salts (17). In the process of cream separation most of the casein is thrown out as skim milk. The remaining portion is thrown out with the fat and these two constituents with the lactose make up the principal solid material in cream. A cream low in fat must, therefore, be high in casein.

The preliminary treatment cream receives in the pasteurization and ripening process before churning tends to precipitate the casein. The degree of precipitation depends upon the duration and intensity of the heat used and the acidity of the cream (14). Thus when the cream is placed in the churn the casein is in a fine granular condition and with the fat globules forms an emulsion (18).

As the cream is agitated during the churning process the individual fat globules coalesce forming a globule of larger size. A continuation of the agitation forms butter granules and when the granules are about 50 mm. in diameter the churning is complete. While the granule is forming small particles of casein or other

nitrogenous compounds are mechanically incorporated which cannot be removed by subsequent washing. The casein that adheres to the outside of the granule or is held mechanically in pockets between the granules may be removed by careful washing and draining.

Casein particles may be present in butter in two forms. The small minute particles, referred to in the preceding paragraph, are invisible and can only be seen when large numbers are suspended in water, forming a milky brine. Under certain conditions of manufacture where the cream is allowed to sour and become lumpy and is then pasteurized, the lumps of curd are hardened, due to the action of heat in the presence of acid. These lumps may remain intact during churning and be finally incorporated, producing the characteristic "speckled" butter sometimes found on the market. This butter shows defective workmanship and would hardly be termed normal because modern buttermakers know how to avoid this condition. Without question some of the analyses showing a high percentage of curd were made from this inferior product. In this study only butter made according to present day knowledge will be considered normal.

In a previous paragraph the fact that some confusion exists as to the definition of the word curd is mentioned. Curd is usually defined as the remaining constituents of butter which are not included under the terms fat, moisture, and salt. It consists mainly of casein, albumin, lactose, lactic acid, and ash. McKay and Larsen (9) state "in the analysis of butter the milk sugar is usually included with the proteids (curd) and the ash is reckoned with the salt."

Guthrie (6) says, "The curd of modern butter contains very little if any albumin, for it is taken out in the washing. The curd, therefore, is largely casein."

Lee and Barnhart (3) express this constituent of butter as casein and ash. Mortensen, Gaessler, and Cooper (12) report this constituent as protein. Thom and Shaw (8) state "The curd is equal to the nitrogen times the factor 6.38." Thompson, Shaw, and Norton (2) state, "The term curd includes the lactose and ash."

It will be seen from the foregoing statements that an accepted or recognized definition of curd has not been established. For this reason the term protein (nitrogen times 6.38) is used throughout this paper.

EXPERIMENTAL WORK

In order to determine the extent that the nitrogenous compounds of milk may be incorporated in butter under factory conditions a number of churnings were made. By varying the methods of churning, washing, and draining an attempt was made to find the amount of nitrogenous substances which might be added to the butter and the conditions which influence their incorporation.

One vat of cream was used for each experiment. After the preliminary vat treatment, as outlined in the vat record, the cream was divided into two churnings. One churning was handled according to good factory methods and served as a check, being normal creamery butter. The remaining portion of the cream was handled so as to make a possible variation in the protein content of the finished butter. The following variations from the normal were used:

1. Unwashed butter.
2. Working butter in buttermilk.
3. Over churning in the presence of buttermilk.
4. Churning at high and low temperatures.
5. Adding starter after churning.

A vat and churn record was completed for each experiment. The duplicate lots of butter were sent to market to find if any variation in score or selling price of the butter would be made.

METHOD OF SAMPLING

When the butter was completely finished and ready to put into tubs small samples were taken from at least twelve parts of the churn. These were placed in a glass jar and covered. The covers were made air tight by dipping in melted paraffin. The samples were then held at 10°F. until analyzed. When

ready for analysis the jars were placed in a water bath at 75–80°F. until the butter was soft enough so that it could be thoroughly stirred and mixed until of salvy consistency.

METHOD OF ANALYSIS

A number of preliminary samples were analyzed to determine the protein content according to official and optional methods. The optional method recommended by Leach (19) was finally adopted for this work. This method was as follows: About 10 grams of the properly mixed sample were weighed on an analytical balance into a tared, flat aluminum moisture dish. The moisture was evaporated from the sample by heating on a hot plate at 100°C. until bubbling ceased. The contents of the dish were then cooled and 50 cc. of petroleum ether were added. The contents of the dish were next washed with petroleum ether on to a filter paper and the residue washed approximately free from fat with repeated washings of petroleum ether. The residue was then allowed to dry on the filter paper which was then transferred to a Kjeldahl digestion flask and the nitrogen determined according to the Gunning (20) method. The protein was calculated as follows:

$$\frac{\text{Nitrogen} \times 6.38}{\text{Amount of sample}} \times 100 \text{ equals per cent of protein.}$$

In all cases triplicate determinations of each sample were made.

METHOD OF CHURNING

The normal churnings in the following experiments were made according to a standard method and represent butter manufactured under modern factory conditions. As these churnings were made during the winter and spring months a variation in churning temperature was necessary, due to the seasonal change in the composition of butterfat. The chief variation between the normal and special churnings was in the washing, working, and draining of the butter. The standard method used in all normal churnings was as follows: When the butter granules were

about 50 mm. in diameter the buttermilk was drawn off and, using a hose, water was sprayed over the butter and allowed to drain out through the open churn gate. Enough wash water was used in this manner to free the churn and butter granules from excessive buttermilk. When the wash water was but slightly turbid the churn gate was closed and enough water was added to the churn to float the butter. The churn was revolved several times, without the workers, to wash the butter granules. The workers were then engaged and the butter worked in the wash water several revolutions of the churn. The water was drawn off first through the churn gate and finally carefully drained through the partly opened churn cover. The butter was then tested for moisture, salted, and finished.

The special churnings in this experiment (table 1) were handled in the same manner as the normal churnings until the churning process was complete. The buttermilk was then drawn off through the churn gate as completely as possible and the butter carefully drained from unincorporated buttermilk by revolving the churn several times and allowing the buttermilk to drain out of the partly opened churn cover after each revolution. The butter was then salted and finished without washing. The butter of the special churnings compared favorably as to flavor, body and color with the butter of the normal churnings which were made from the same vat of cream.

The special churnings in this experiment (table 2) were handled to the end of the churning process in the same manner as the normal churnings. Then one-half of the buttermilk was drawn off and the butter worked in the buttermilk. The remaining buttermilk was drawn off as thoroughly as possible through the churn gate and then carefully drained by revolving the churn several revolutions and allowing the buttermilk to drain out through the partly opened churn cover. When most of the unincorporated buttermilk had been removed in this manner, the butter was salted and finished without washing. The body and flavor of the butter in the special churnings were similar to that of the normal churnings which were made from the same vat of cream.

TABLE 1

To determine the effect of washing upon the protein content of butter; vat and churn record

	VAT 1		VAT 2		VAT 3		VAT 4	
Churning	Special	Normal	Special	Normal	Special	Normal	Special	Normal
Condition of cream	Good	Good	Good	Good	Good	Good	Good	Good
Pounds of cream in churn	804	804	797	797	739	739	841	841
Per cent of fat in cream	40	40	40	40	34	34	35	35
Per cent of acid before neutralization	0.42	0.42	0.33	0.33	0.48	0.48	0.47	0.47
Per cent acid at the churn	0.28	0.28	0.33	0.33	0.25	0.25	0.34	0.34
Temperature of pasteurization for 30 minutes, °F	145	145	145	145	145	145	145	145
Temperature held in vat, °F	45	45	44	44	45	45	45	45
Time held in vat, hours	3	3	2	2	20	20	3	3
Churning temperature, °F	50	50	48	48	53	53	49	49
Churning time, minutes	20	28	30	30	25	18	45	50
Temperature of buttermilk, °F	57	58	56	56	56	56	55	56
Times washed	None	2	None	2	None	2	None	2
Temperature of wash water, °F		58		56		54		56
Revolutions worked in wash water	None	12	None	7	None	9	None	13
Total revolutions worked	35	47	15	25	25	35	26	44
Method of draining	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover
Per cent of protein	0.5406	0.4012	0.4542	0.3155	0.5505	0.3782	0.5252	0.4372

TABLE 2

To determine the effect upon the protein content of the finished butter by working the butter in the buttermilk; vat and churn record

	VAT 1		VAT 2		VAT 3	
Churning	Special	Normal	Special	Normal	Special	Normal
Condition of cream	Good	Good	Good	Good	Good	Good
Pounds of cream in churn	784	784	834	834	694	694
Per cent of fat in cream	30	30	37	37	42	42
Per cent of acid before neutralization	0.36	0.36	0.36	0.36	0.32	0.32
Per cent acid at the churn	0.35	0.35	0.31	0.31	0.33	0.33
Temperature of pasteuring for 30 minutes, °F	145	145	145	145	145	145
Temperature held in vat, °F	45	45	45	45	45	45
Time held in vat, hours	2	2	17	17	20	20
Churning temperature, °F	49	49	56	56	56	56
Churning time, minutes	50	25	25	20	25	15
Temperature of buttermilk, °F	58	57	58	58	59	58
Times washed	None	2	None	2	None	2
Temperature of wash water, °F		56		58		58
Revolutions worked in wash water	None	5	None	5	None	6
Revolutions worked in buttermilk	10	None	10	None	20	None
Total revolutions worked	46	24	40	20	35	19
Method of draining	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover	Gate and cover
Per cent of protein	0.5562	0.4189	0.5064	0.3476	0.5166	0.3676

TABLE 3

To determine the effect of adding starter to the butter upon the protein content of the finished butter; vat and churn record

	VAT 1	
Churning	Special	Normal
Condition of cream	Good	Good
Pounds of cream in churn	587	587
Per cent of fat in cream	38	38
Per cent of acid before neutralization	0.40	0.40
Per cent acid at the churn	0.30	0.30
Temperature of pasteurization for 30 minutes, °F	145	145
Temperature held in vat, °F	45	45
Time held in vat, hours	16	16
Churning temperature, °F	54	54
Churning time, minutes	15	20
Temperature of buttermilk, °F	56	56
Times washed	1	2
Temperature of wash water, °F	56	56
Revolutions worked in wash water	None	6
Revolutions worked after adding starter	10	None
Total revolutions worked	23	36
Method of draining	Gate and cover	Gate and cover
Per cent of protein	0.4718	0.3155

The special churning in this experiment (table 3) was handled in the same manner as the normal churning until the butter granules were of the desired size. After carefully washing the butter granules with a spray of water from a hose, four gallons of ordinary starter were added to the churn. The butter was then worked ten revolutions of the churn. The excess starter was then drained off and the butter salted and finished without washing. It is apparent that all of the starter which was added could not be incorporated without over working the butter.

In order to determine the effect of abnormally high churning temperature upon the protein content of the finished butter two churnings were made in a ten gallon barrel churn.

In churning number one the cream was pasteurized, ripened, and then churned at 60° F. This butter was carefully worked and drained but was not washed. The body of this butter was

TABLE 4

CHURN NUMBER	PER CENT BUTTER FAT	ACIDITY	CHURNING TIME	MOISTURE	PER CENT PROTEIN
1	34	0.35	25	17	0.4900
2	18	0.80	20	20	0.5915

somewhat weak but represented a good quality of farm dairy butter.

The cream for the second churning was placed at 70° F. for four days and allowed to ripen spontaneously. The cream was pasteurized and then churned at 65° F. When the churning was complete the buttermilk was nearly all removed and the butter was worked to incorporate as much buttermilk as possible. This butter was not washed. The butter in this churning represented an unsatisfactory grade of farm dairy butter.

The number of churnings in the foregoing experiments are not extensive enough to be conclusive but the results obtained from the analysis of the butter were so uniformly constant that further churnings were not deemed necessary.

SUMMARY

The average protein content of the normal samples of butter in these experiments was 0.3727 per cent.

The average protein content of the butter which was worked in the buttermilk was 0.5264 per cent.

The average protein content of the unwashed butter was 0.5177 per cent.

The average loss of protein due to washing the butter was 0.1450 per cent.

The protein content of the unwashed butter, churned at abnormally high temperature, was 0.5407 per cent.

The protein content of the butter to which starter had been added was 0.4718 per cent.

Nitrogenous compounds were not incorporated in the butter to any appreciable extent by using the methods of manufacture followed in these experiments.

One per cent was found to be sufficient allowance for all the constituents of butter which may be classified under the term curd.

By incorporating 15.5 per cent moisture and allowing 1 per cent for curd as much as 3.5 per cent of salt may be incorporated without reducing the fat content of the butter below 80 per cent.

No difference in score or selling price of the duplicate lots of butter was made upon the Chicago market.

Speckled butter was not found in any of the samples.

Milky brine was not found in any samples of the finished butter.

With the exception of one churning the keeping quality of the washed butter was slightly better than that of the unwashed butter.

CONCLUSION

Excessive overrun is probably due to the incorporation of moisture and not to curd under modern factory conditions.

REFERENCES

(1) United States Department of Agriculture Yearbook. 1913, p. 487.

(2) Thompson, S. C., Shaw, R. H. and Norton, R. P. 1912 The normal composition of creamery butter. Bureau of Animal Industry Bulletin 149, p. 3.

(3) Lee, Carl E., and Barnhart, Jesse M. 1909 Composition of market butter. Ill. Expt. Station Bulletin 139, p. 450.

(4) Sorensen, James 1918 Minnesota butter analyzed. Chicago Dairy Produce, August 6, 1918, p. 32.

(5) McKay, G. L. 1918 Statements on the subject of definitions and standards of butter presented to the joint committee on definitions and standards, p. 90.

(6) Guthrie, E. S. 1916 The Book of Butter, pp. 174, 11.

(7) Jensen, O. A. 1910 Bacteriological studies of Danish butter. Rev. Gen. Lait. 8 (1910), No. 18, p. 409.

(8) Thom, Chas., and Shaw, R. H. 1915 Moldiness in butter. Jour. Agr. Res., 3: no. 4, p. 304.

(9) McKay, G. L., and Larsen, C. 1910 Principles and Practice of Buttermaking, pp. 246, 247, 281, 282.

(10) MICHELS, JOHN 1904 Creamery Butter-Making, p. 103.
(11) WING, HENRY H. 1911 Milk and Its Products, pp. 143–147.
(12) MORTENSEN, M., GAESSLER, W. G., AND COOPER, W. H. 1914 Pasteurization of cream for buttermaking. Iowa Expt. Station Bulletin 156, p. 15.
(13) STOCKING, WM. A., JR. 1917 Manual of Milk Products, p. 254.
(14) HUNZIKER, O. F. 1920 The Butter Industry, pp. 219, 547.
(15) STORCH. Bericht des Koenigl. Veterinar- und Landbanhochschule-Laboratoriums, Kopenhagen, Denmark.
(16) VAN SLYKE, L. L. 1912 Modern Methods of Testing Milk and Milk Products, p. 11.
(17) SOMMERS, H. H., AND HART, E. B. 1919 The heat coagulation of milk. Jour. Biol. Chem., 40, no. 1, November, 1919, p. 137.
(18) FISHER, M. F., AND HOOKER, M. O. 1917 Fats and Fatty Degeneration, p. 19.
(19) LEACH, A. E. 1914 Food Inspection and Analysis, p. 534.
(20) GUNNING 1914 Food Inspection and Analysis. Leach, p. 145.

FACTORS INFLUENCING THE VISCOSITY OF SWEETENED CONDENSED MILK

L. A. ROGERS, E. F. DEYSHER AND F. R. EVANS

From the Research Laboratories of the Dairy Division, United States Department of Agriculture

In preparing sweetened condensed milk for the market it is essential that the viscosity shall not vary beyond certain limits. It must be sufficiently viscous to give the milk a smooth creamy consistency, but should not become, at any stage, so thick that it will not flow freely. There is, however, a tendency for condensed milk to gradually become thicker on standing until in some cases it acquires a jelly-like consistency and will not flow from the can. Two types of thickening may be distinguished by superficial examination. In one the thickening is not uniform throughout the can but usually begins at the top and gradually extends downward until the entire can is affected. The curd is of a pasty texture and when mixed with water, remains in the form of insoluble flecks. This type of curd is usually associated with unpleasant changes in flavor and odor and is undoubtedly due to the action of bacteria.

In the type of thickening with which this paper is concerned the increase in viscosity proceeds uniformly throughout the can, and there is no marked change in flavor. No real curd is formed and the thickened milk can be mixed with water without the separation of definite flecks. In the earlier stages agitation will restore the milk, partially at least, to its original fluid condition, but in time it takes on a jelly-like consistency which can not be removed. There are many reasons for believing that this slow change which takes place sooner or later in all condensed milk is not due to the growth of bacteria. The fact that no correlated bacterial multiplication has been detected is not conclusive, although it can be admitted as negative evidence. Other evidence which will be brought forward in this paper leads us to

believe that it is a physical change in the milk controlled by various factors in which bacteria have no direct part.

The full explanation of these changes requires a knowledge of the physical chemistry of a highly complex fluid, a knowledge which is still inadequate. It is possible, however, to determine by empirical methods some of the factors influencing these changes without attempting to explain the nature of the change itself.

EXPERIMENTAL METHODS

The condensed milk used in these experiments was made for the most part in balloon flasks of about 10 liters capacity. Three of these flasks were suspended in a common water bath and each connected through a condenser and a graduated receiver with a pump giving a vacuum of about 28 inches. Stopcocks permitted the milk to be drawn slowly into the flasks. On the whole the equipment simulated very closely the commercial process, but permitted the manufacture of three batches at once from the same lot of milk with a very accurate control of the product. Knowing the composition of the raw milk, the amount of water to be removed to obtain any desired composition could be calculated and the water distilled measured roughly on the graduated receiver. The final point at which the condensation was stopped was determined by disconnecting the flask from the apparatus and weighing on a balance accurate to 10 grams. The usual batch was 3500 grams of raw milk. Unless otherwise stated skim milk was used, because by eliminating the fat in the milk the product was made slightly less complicated. The milk was produced on the Dairy Division farm and was of good quality.

The finished milk was cooled by rotating the condensing flask slowly in a tank of water starting with the water at the temperature of the milk and cooling it slowly to about 20°C. (68° F.) In addition to this laboratory equipment the laboratory is provided with a small pan having a capacity of about 15 gallons of finished product. This equipment is identical in its arrangement with that of the ordinary condensery except that in place of the

usual spray condenser a surface condenser provides for the collection and measurement of the distillate. The condensed milk was held in ordinary soldered-cap baby-size cans, and was stored at 30°C. (86° F.) This temperature represents the extreme rather than the normal condition, but was adopted because it increased the rapidity of the change and gave quicker results.

The viscosity of the finished milk was measured in a viscosimeter designed by Dr. Clark of this laboratory. It consisted esentially of a heavy brass cylinder suspended by a steel wire in a larger cylinder which was revolved by an electric motor held automatically at a constant speed. The revolving cylinder was water-jacketed and held at a temperature of 40°C. (104° F.) by a thermostat and electric heater. The milk was warmed to 40°C. (104° F.) before it was transferred to the viscosimeter. The rotation of the suspended cylinder due to the viscosity of the milk was read from a pointer moving over a graduated circle, or for the more minute changes by a telescope reading a scale reflected in a small mirror set in the top of the cylinder.

Unless otherwise stated the viscosimeter readings given in the tables are in degrees indicated by the pointer, which have a value about twice the degrees of the telescope scale. The readings have not been standardized and have a relative value only. Normal condensed whole milk should give a reading of 5 to 12 degrees on the pointer or 10 to 24 degrees on the telescope scale.

FACTORS WHICH APPARENTLY DO NOT AFFECT VISCOSITY

There are certain steps in the usual process of making condensed milk which might reasonably be expected to have an influence on the viscosity but which so far as we have been able to determine have in fact little or no effect. In consideration of the well-known catalytic action of salts of copper and its detrimental effect in certain other dairy products, it would not be unreasonable to suppose that it would have some influence on condensed milk. Experiments in which the milk was heated by steam forced through a coil of small copper tubing and others in

which copper salts were added directly to the milk failed to show any increase in viscosity over the check.

Sweetened milk is not usually homogenized, but it may be of some interest to state that, while this has the effect of increasing the initial viscosity it is without appreciable effect on the progressive increase in viscosity. This is shown by table 1 which gives the result of an experiment in which one half of a batch of milk was homogenized at 3000 pounds pressure. The initial viscosity of the homogenized lot was higher than the check, but there was no marked difference in the rate at which it increased in the two samples.

TABLE 1

Effect of homogenizing on viscosity. Milk solids 28 per cent, fat 7.76 per cent, forewarming temperature 63°C. (145.4° F.) storage temperature, 30°C. (86° F.)

AGE	NOT HOMOGENIZED	HOMOGENIZED AT 3000 POUNDS PRESSURE
days	*rotation, degrees*	*rotation, degrees*
1	3.4	8.8
8	3.6	12.8
15	5.0	18.3
31	13.1	18.6

Notwithstanding the fact that the milk is exposed for the greater part of the condensing process to a high vacuum, the milk in the cans contains a considerable proportion of air from which the oxygen disappears in about two weeks. Evidently the oxygen combines with some constituent of the milk and it is not unreasonable to suppose that it may have some effect on the viscosity. We have been unable, however, to find that it has any appreciable effect. Table 2 shows the progressive change in viscosity in a lot of condensed skim milk one-half of which was sealed in cans in the usual way at atmospheric pressure. The remainder was drawn slowly into an evacuated flask to remove the greater part of the contained air, and transferred at once to glass bulbs holding about 150 cc.

These bulbs were evacuated by a Geryk pump which reduced the pressure rapidly to a fraction of a millimeter. At this very low pressure there was considerable ebullition of the milk, due

possibly to the escape of water vapor. The neck of the bulb was sealed off. At 30°C. (86° F.) the change in viscosity was so slight that it could be measured with the telescope throughout the storage period and was practically identical for the bulbs and the cans.

TABLE 2

Influence of contained air on viscosity. Milk solids 26 per cent, forewarming temperature 63°C. (145.4° F.), storage temperature 30°C. (86° F.)

AGE	CANS SEALED AT ATMOSPHERIC PRESSURE	EVACUATED BULBS
days	*rotation, degrees**	*rotation, degrees**
4	2.1	2.1
18	3.1	2.5
33	3.6	2.9
67	4.8	4.3
88	7.5	9.3
116	14.2	13.0

* Scale.

TABLE 3

Influence of acidity on viscosity. Milk solids 26 per cent, fat 0, forewarming temperature 63°C. (145.4° F.), storage temperature 30°C. (86° F.). Acidity increased with lactic acid

BEFORECONDENSING.	*pH* 6.51	*pH* 6.41	*pH* 6.30	*pH** 6.63
AFTER CONDENSING..	6.17	6.10	6.00	6.36
days	*rotation, degrees†*	*rotation, degrees†*	*rotation, degrees†*	*rotation, degrees†*
2	3.4	3.0	3.3	3.5
10	3.4	3.1	3.4	4.0
17	3.4	2.8	3.6	4.1
30	3.6	3.6	3.8	4.3
58	6.3	4.1	4.2	

* Neutralized from 6.30.

† Scale.

The acidity of the milk is another factor which would be expected to influence the viscosity. It has been shown by Wolfgang (1) that very small changes in the hydrogen ion concentration have a marked effect on the viscosity of albumen solutions. Table 3 shows the result of an experiment in which the acidity of the original milk was changed by the addition of

lactic acid. The reaction of the milk both before and after condensing is shown in terms of hydrogen ion concentration as determined for us electrometically by Dr. Clark of this laboratory. It should be remembered that the acidity varies inversely as the pH of Sorensen's scale. In this experiment the acidity of the milk was increased from a pH of 6.51 as shown in the first column, to 6.30 by the addition of lactic acid. The acidity of the milk shown in the fourth column was neutralized from 6.30 to 6.63 as shown in the last column. The initial viscosity of all of this milk was low and held almost without change for 58 days at 30°C. There was no real difference in the viscosity of the various lots. In one experiment in which the reaction of the milk was very materially changed it became thick in the pan, but we have been unable to find that any variation in the acidity within reasonable limits has an appreciable influence on the viscosity.

The cane-sugar concentration has only a minor influence on the initial viscosity and probably none at all on the progressive increase in viscosity.

This is illustrated by the results shown in table 4 and figure 1. In this experiment the three lots of milk were identical except in the quantity of added sugar. Since the preserving action of the sugar is dependent on the concentration of its aqueous solution and not on its relation to other constituents of the milk, it is given in this table and elsewhere in this paper in terms of its solution. Obviously this is not strictly accurate, because we have no way of knowing what part of the water is available for dissolving the sugar, but on the whole it gives a much more satisfactory indication of the conditions than the usual way of expressing it as a percentage of the milk.

In two weeks the viscosity varied slightly, but in direct proportion to the sugar content. The viscosity of the milk containing 62 per cent and 58 per cent sugar solution increased slightly in thirty-two days but maintained their initial relation. On the other hand the milk containing a 54 per cent sugar solution increased in viscosity slowly at first but with increasing rapidity until at thirty-two days it was a firm jelly. The odor

and flavor of this milk as well as the nature of the curd indicated that the low sugar concentration permitted the growth of bacteria which, no doubt, accounted for the greatly increased viscosity.

TABLE 4

Influence of cane-sugar concentration on viscosity. Milk solids 28 per cent, fat 0, forewarming temperature 48°C. (118.4° F.), storage temperature 30°C. (86° F.)

AGE	CANE SUGAR CONCENTRATION		
	54 per cent	58 per cent	62 per cent
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
1	1.75	2.0	4.0
13	2.5	3.0	7.5
21	10.25	4.25	7.5
32	38.0	9.0	11.0

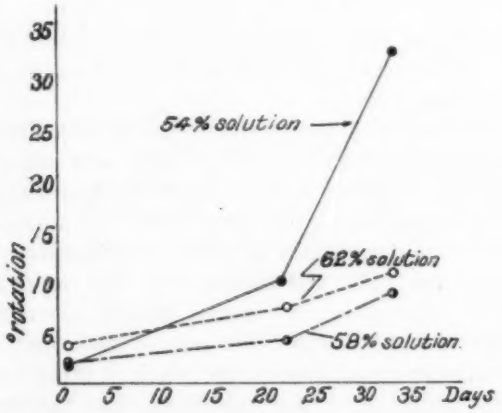


FIG. 1. THE RELATION OF CANE SUGAR CONCENTRATION TO VISCOSITY

INFLUENCE OF STORAGE TEMPERATURE ON INCREASE IN VISCOSITY

No special effort is made to store condensed milk at low temperatures, and in its transportation and sale it is frequently exposed to summer heat for extended periods. It is to be expected that this would tend to thicken the milk. In table 5

TABLE 5

Influence of storage temperature on viscosity. Total solids 71.77 per cent, milk solids 28.57 per cent, fat 8.2 per cent, forewarming temperature 75°C. (161° F.)

AGE	STORAGE TEMPERATURE			
	10°C. (50° F.)	20°C. (68° F.)	30°C. (86° F.)	37°C. (98.6° F.)
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
1	2.5	2.5	2.5	2.5
8			3.0	
11	2.5	3.0		12.0
21	2.5	4.0	7.0	18.0
31	2.5	4.5	9.0	20.0
59	2.5	10.0	15.0	37.0
94	2.5	13.0	16.5	38.0
121	2.5	13.5	16.7	39.0

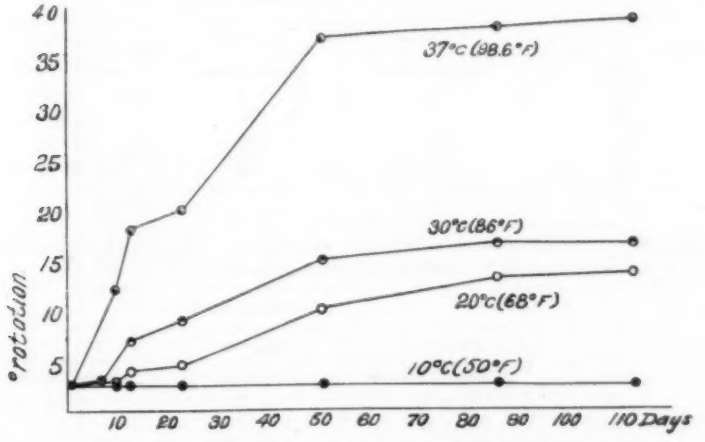


FIG. 2. INFLUENCE OF STORAGE TEMPERATURE ON VISCOSITY

and in fig. 2 are shown the changes in viscosity in whole milk held for 121 days at various temperatures. It is interesting to note that the milk held at 10°C. (50°F.) remained unchanged throughout this period. There was a slow increase in viscosity at 20°C. (68° F.) and at 30°C. (86° F.). An additional 7° made a much greater difference in the viscosity than the 20° change

from 10°C. (50° F.) to 30°C. (86° F.). The nature of the thickening in the milk held at 37°C. (98.6° F.) did not suggest bacterial fermentation, nor have we been able to find by plating any evidence of bacterial growth which would account for this change.

THE INFLUENCE OF THE COMPOSITION OF THE MILK ON VISCOSITY

It is a matter of common knowledge that if milk is concentrated beyond a certain point it will become thick in a short time. The relation of the concentration of the milk solids of

TABLE 6

Relation of concentration of milk solids to viscosity. Skim milk, forewarming temperature 80°C. (176° F.); storage temperature 30°C. (86° F.)

AGE	MILK SOLIDS NOT FAT		
	24 per cent	26 per cent	28 per cent
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
1	2.0	3	5.25
12	3.0	10	25.0
24	5.0	19	130.0
34	7.5	25	Beyond range

TABLE 7

Relation of concentration of milk solids to viscosity. Skim milk, forewarming temperature 60°C. (140° F.); storage temperature 30°C. (86° F.)

AGE	MILK SOLIDS NOT FAT		
	20 per cent	24 per cent	28 per cent
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
1	0.5	1.25	2.25
13	1.0	1.0	2.5
25	1.0	1.0	4.0
35	1.0	1.0	8.0

skim milk to the increase in viscosity is shown in table 6. The tendency to become thick on standing is evidently not in a direct relation to the concentration of the milk solids but increases more rapidly as the concentration becomes greater. This relation varies with different milks, but we have always found a greatly increased tendency to thicken in passing from 26 to 28 per cent milk solids in skim milk.

It became evident very early in this work that factors other than the concentration of the milk solids had an important influence on the viscosity. Table 7 shows the changes in viscosity of three batches of milk treated in every way the same as

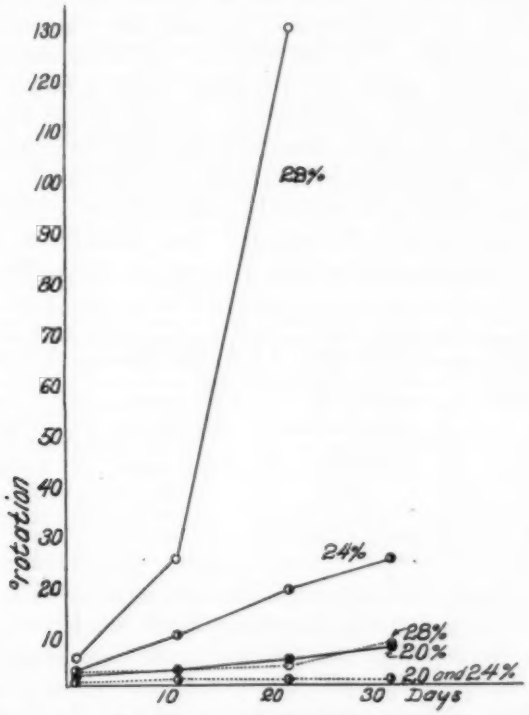


FIG. 3. INFLUENCE OF CONCENTRATION AND FOREWARMING TEMPERATURE ON VISCOSITY

Solid lines: forewarmed to 80°C. (176° F.)
Dotted lines: forewarmed to 60°C. (140° F.)

those in table 6, except that those in table 6 were forewarmed to 80°C. (176° F.), while those in table 7 were not heated above 60°C. (140° F.) The very marked difference in these milks is brought out more clearly in figure 3, in which the viscosity of

the milk with high forewarming is shown by solid lines while the low-forewarmed milk is shown by broken lines. This effect of high forewarming has been shown by repeated experiments, although the increase in viscosity due to high heating has not always been so marked as in the experiment cited in this table.

Not all of the constituents of the milk are concerned in this change in viscosity. The fat exists as very small globules floating in the serum and in all probability is not a factor in determining the viscosity. It is difficult to vary the fat in a normal manner and at the same time hold the other constituents constant. Two experiments in which the fat was varied in different ways indicated that it was not an important factor in the viscosity.

This is also true of the lactose. Any variation of this constituent within reasonable limits has only a minor effect.

TABLE 8

Relation of casein and albumen to viscosity. Lactose content 16.44 per cent; forewarming temperature 96°C. (204.8° F.); storage temperature 30°C. (86° F.); fat 0 per cent

AGE	NORMAL SKIM MILK	CASEIN REMOVED	CASEIN AND ALBUMEN REMOVED
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
2	18	6	1
9	130	8	1
32	Beyond range	15	1

The proteins, the casein, and the albumen are in a different category. Their colloidal condition, their well known instability under the action of heat and the rapid changes produced in their structure by the activities of bacteria would lead one to expect them to be of primary importance in determining the viscosity of condensed milk.

On account of the complex nature of the milk constituents and their intimate relation to one another it is impossible to separate them in such a way that the effect of each can be determined accurately, but some indication may be obtained by experiments similar to that shown in table 8. A lot of skim milk was divided into three portions, one of which was condensed without further alteration. The two remaining portions were acidified, the

precipitated casein removed by filtration, and the reaction of the filtrate corrected. One of those containing the albumen, lactose, and salts was evaporated. The albumen was removed from the third portion by adjusting the reaction and heating. All three were forewarmed to 96°C., and since they could not very well be brought to an equal concentration of total solids they were evaporated to a uniform lactose content of 16.44 per cent. The cane-sugar concentration of the finished milk was 60 per cent in each case. The original milk increased in viscosity very rapidly; the portion from which the casein had been removed, much more slowly; and the one containing only lactose and salts remained at the initial very low viscosity.

TABLE 9

Relation of casein and albumen to viscosity. Fat removed; lactose 16.3 per cent; forewarming temperature 63°C. (145.4° F.); storage temperature 30°C. (86° F.)

AGE	NORMAL SKIM MILK	CASEIN REMOVED	CASEIN AND ALBUMEN REMOVED, CASEIN REPLACED
days	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
2	3.0	1	1
9	2.5	1	1
30	4.5	1	8
74	37.0	1	130

Similar results were obtained by a variation of this procedure. A lot of skim milk was divided into three parts, one of which was condensed without further change. The casein was removed from the other portions. One of these containing the albumen, sugar, and ash was evaporated. The albumen was removed from the third portion by heat and the casein, redissolved in alkali, was returned giving a milk free from albumen. Sugar was added to each portion to give a 60 per cent solution in the finished milk, and all were evaporated to a uniform lactose content of 16.3 per cent. This experiment differed also from the previous one in that the forewarming temperature was 63°C. (145.4° F.) instead of 96°C. (204.8° F.). The changes in viscosity of these milks are shown in table 9.

The normal milk increased in viscosity slowly, but even at seventy-four days was much less viscous than the highly heated milk of the previous experiment when only nine days old. The very low initial viscosity and lack of change in the milk from which casein was removed indicates that the albumen is a factor only when it has been heated above its coagulating point. The precipitated and redissolved casein shown in the fourth column of table 9 could not be expected to react exactly like casein in normal milk, and we find that while the initial viscosity of the third portion, containing the redissolved casein, was low, it had increased at seventy-four days to 130°. Although this is not exactly comparable with the normal milk, it may be taken as evidence that the casein is the most significant factor in determining the viscosity of sweetened milk. The relation of the albumen to the change in viscosity was also shown by varying the albumen content of the milk by the addition of egg white. The chemical and physical nature of this material is so nearly identical with the lactalbumen of the milk that there is little doubt that it would have the same effect on the viscosity.

When the forewarming temperature was above 90°C. (194° F.) the initial viscosity and the increased viscosity at various storage periods were in direct relation to the amount of albumen added. On the other hand when the forewarming temperature was held below 60°C. (140° F.) the initial viscosity was the same for all lots and the changes, which were small, had no relation to the albument content of the milk.

The temperature of the pan under ordinary circumstances is too low to affect the albumen or the casein. There is a possibility that the layer of milk in immediate contact with the coil may be momentarily heated considerably above the temperature indicated by the thermometer. A resistance thermometer made especially for this purpose and held so that it was in close contact with the surface of the coil did not give readings appreciably higher than the mercury thermometer projecting through the wall of the pan.

More positive results were obtained by arranging the coils so that they could be heated by circulating water through them at

any desired temperature. Even when the water was held as low as 70°C. (158° F.), the viscosity did not differ from that portion of the milk made in the usual way with steam heated coils. The long exposure to heat which was made necessary by the low temperature of the coils did not affect the viscosity.

THE INFLUENCE OF THE ASH CONSTITUENTS

The ash, of course, must not be considered as so much mineral matter in solution in the milk, but as it exists in combination with other constituents of the milk, particularly the casein. It is well known that a certain part of the calcium and the phosphorus exist in the milk in some kind of combination with the casein, and that the stability of the casein is dependent to some extent on this combination.

Sommer and Hart (2) have shown that the temperature at which milk coagulates is controlled, in some degree at least, by the interrelation of the ash constituents. It is also well known that the relation between the casein and its mineral ingredients are more or less disturbed by heat. It is not unreasonable, therefore, to suppose that variations in the ash constituents would have some influence on the viscosity of the concentrated milk.

On account of the difficulties in the way of removing any part of the ash from the milk, it is practicable to vary the mineral matter only by the addition of the separate salts. The combination existing between the ash constituents and the casein and between the ash constituents themselves is still a matter of speculation, and it is obvious that a change in the composition of the ash made in this way cannot be exactly comparable to variations occurring normally.

When one of the normal mineral salts of the milk is added to milk we are unable to say definitely what rearrangements it may bring about, but its effect on the behavior of the milk when exposed to different physical reactions may be taken as an indication of the effect of similar variations occurring normally. According to Van Slyke and Bosworth, (3) normal milk con-

tains 0.274 per cent of citrates in the form of the calcium and potassium salts. On this basis 3500 grams of skim milk, which was the standard batch used in our experimental work, should contain approximately 9.9 grams of total citrates. The addition to 3500 grams of milk, of citrates in the form of calcium citrate in amounts up to 2.8 grams had no appreciable effect on the viscosity when the milk was held at 30°C. (86° F.) for 58 days. This represents an increase in the total citrates of about 28 per cent.

Somewhat different results were obtained by the addition of phosphates. The effect of the addition of molecular quantities of the monobasic and dibasic potassium phosphates is shown

TABLE 10

Effect of variation in phosphates. Milk solids 26 per cent; fat 0 per cent; forewarming 63°C. (145.4° F.)

PHOSPHATES ADDED	BEFORE CONDENSING	AFTER CONDENSING	VISCOSITY				
			1 day	10 days	18 days	29 days	86 days
	pH	*pH.*	*rotation,* degrees*	*rotation,* degrees*	*rotation,* degrees*	*rotation,* degrees*	*rotation,* degrees*
7 cc. $\frac{m}{1}$ KH_2PO_4	6.45	6.15	3.9	5.2	5.5	6.2	20.0
7 cc. $\frac{m}{1}$ K_2HPO_4	6.56	6.24	3.3	4.3	4.8	5.0	33.0
None	6.44	6.21	3.0	3.1	3.2	3.35	18.5

* Scale.

in table 10. The hydrogen ion determinations, made both before and after condensing, show that these additions had only slight effect on the acidity. The acidity of the milk was distinctly reduced by the addition of the tribasic salt, but this batch was lost. In any case the change in hydrogen ion concentration would be within the limits which we have found to be without effect on the viscosity.

The check milk to which no salt was added was lower in viscosity than any of the others, but the difference was so slight that it can hardly be considered significant. The degrees given in this table are scale readings and indicate a low viscosity even

at eight-six days. The monobasic salt added represents, on the basis of Van Slyke and Bosworth's calculations, an increase in the total phosphates in the milk of about 5 per cent. In another experiment the results of which are given in table 11, slightly larger amounts of the three salts were added. In this case there was no significant difference in the initial viscosity or at eleven days, but at twenty-three days and particularly at forty-four days the three lots to which phosphates were added were decidedly more viscous than the check lot. It should be noted that this is equally true of the monobasic salt which increases the acidity and of the tribasic salt which decreases it. Similar but more marked results were obtained when still larger amounts of salt were added.

TABLE 11

Influence of phosphates on viscosity. Milk solids, 26 per cent; fats 0 per cent; forewarming 68°C. (145.4° F.)

PHOSPHATES ADDED	$\frac{m}{l}$	GRAMS	INCREASE IN TOTAL PHOSPHATES	VISCOSITY			
				1 day	11 days	23 days	44 days
	cc.		*per cent*	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*
KH_2PO_4	10	1.36	7.3	1.4	2.0	56	140
K_2HPO_4	10	1.74	9.4	1.5	2.0	9	100
K_3PO_4	10	2.12	11.4	1.8	2.6	13	120
None				1.5	1.7	2	15

THE INFLUENCE OF FOREWARMING TEMPERATURES ON THE SEPARATION OF FAT

Nearly all of the experimental condensed milks mentioned in this paper were made from skim milk, and consequently the separation of the fat was not a factor to be considered. It was noticed, however, that in some lots made from whole milk there was a tendency for the fat to separate. In evaporated milk, before homogenization came into general use, it was considered necessary to heat the milk high enought to produce a soft curd, not only to give the milk a satisfactory "body," but also to make it sufficiently viscous to hold the fat in suspension. The viscosity of sweetened milk is usually high enough to accomplish

this purpose, but if the forewarming temperature is low there is a possibility that an objectionable separation of fat may occur.

A comparison of the effect of high and low forewarming temperatures was made by dividing a lot of milk into two portions, one of which was heated to 95°C. (203° F.) by the jacket, while the other part was held thirty minutes at 63°C. (145.4° F.). After condensing in the laboratory pan half of the latter batch was homogenized at 3000 pounds pressure. The results are given in table 12.

TABLE 12

Influence of forewarming temperature on separation of fat. Total milk solids 28 per cent; sugar solution 60 per cent; storage temperature 30°C. (86° F.)

FOREWARMING TEMPERATURE	HOMOGENIZING PRESSURE	VISCOSITY				SEPARATION OF FAT, AFTER 29 DAYS
		1 day	8 days	15 days	29 days	
	pounds	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*	*rotation, degrees*	
63°C. (145.4° F.).....	Not homogenized	3.0	4	7	14.5	Slight
63°C. (145.4° F.).....	3000	7.0	12	16	20.0	Slight
95°C. (203° F.).....	Not homogenized	9.5	26	37	47.0	None(?)

In the lot forewarmed at 95°C. there was at the most only a very slight separation of fat. In the two lots forewarmed at 63°C. there was a noticeable but not objectionable separation of fat. This was slightly less noticeable in the homogenized half.

In another experiment made in the same way the viscosity of the low forewarmed milk was exceptionally low, and there was a decided separation of the fat. This did not occur in the homogenized half nor in the lot forewarmed at a high temperature.

SUMMARY

Acidity within reasonable limits, contained air, and the salts of copper have no significant influence on the increase of viscosity of sweetened milk. Cane sugar increases the initial viscosity slightly, but affects the increase in viscosity only as it inhibits the growth of bacteria.

The increase in viscosity is more rapid at higher storage temperatures, but this increase is not in direct relation to the temperature. The effect of the temperature is very slight at 20°C. (68° F.) or lower, but is marked at 30°C. (86° F.) or higher.

The tendency to thicken on standing increases with, but not in direct relation to, the concentration of solids not fat.

The casein is the constituent principally concerned in the production of the viscosity. The albumen is a factor when the forewarming temperature is much above its coagulating point.

The phosphates, probably through their combination with the casein, may have influence on the change in the viscosity. An increase in the total phosphates of the raw milk by as much as 7 per cent will cause a distinct acceleration in the progressive increase in viscosity.

The tendency of the milk to thicken is greatly increased by the high temperature ordinarily used in the forewarming. Satisfactory results from a bacteriological standpoint may be obtained to about 63°C. (145.4° F.) for twenty to thirty minutes. The viscosity of the product made in this way is low, and the tendency for the viscosity to increase in storage is much reduced. When the viscosity is very low in condensed milk made with low forewarming temperature, there is a tendency for the fat to separate. It is not probable that this condition would occur in large batches of milk made under commercial conditions.

REFERENCES

(1) WOLFGANG, PAULI 1913 The viscosity and electrochemistry of protein solutions. Trans. of Faraday Soc., ix, pts. 1–2, 54–56.

(2) SOMMER, H. H., AND HART, E. B. 1919 The heat coagulation of milk. *In* Jour. Biol. Chem., xl, no. 1, 137–151.

(3) VAN SLYKE, L. L., AND BOSWORTH, A. W. 1914 Condition of casein and salts in milk. N. Y. Agr. Expt. Sta., Tech. Bul. no. 39.

BITTERNESS IN EVAPORATED MILK

GEORGE SPITZER AND W. F EPPLE[1]

Purdue University Agricultural Experiment Station, Department of Dairy Husbandry, Lafayette, Indiana

In the fall of 1919 a prominent milk condensory experienced considerable difficulty with evaporated milk becoming bitter. This bitterness did not occur in all cans, though made from the same batch of milk sterilized and treated uniformly. The physical appearance of the evaporated milk was normal in every respect, the characteristic bitterness was the only objectionable feature Some preliminary work was done with the bitter milk, and it was found that ordinary chemical tests failed to reveal any cause for this condition. Plate cultures were made of this bitter milk which showed the presence of an organism. Sterilized sweet milk was inoculated with this organism and it also became bitter. From the appearance of the plate culture there seemed to be present only one type of organism, and this was later found to be correct.

OBJECT OF THE EXPERIMENT

The object of the following experimental work was to identify this organism, to determine its thermal death point and its proteolytic action on milk proteins, and to make a study of the enzymes produced by it.

EXPERIMENTAL

1. Bacteriological study

A number of cultures of this organism have been studied both morphologically and culturally. The following is a general description of the organism.[2]

[1] Acknowledgment is due to E. G. Sieveking, Student Assistant.

[2] Credit is here given to I. L. Baldwin of the Biology Department for the description of this organism.

Morphology. Form: The organism is definitely rod shaped with rounded ends. When freshly isolated from milk it shows definite capsules which stain readily with gentian violet. Upon continued growth on artificial media it tends to lose its property of forming definite capsules

Size: About 0.4 by 2 microns are the average dimensions of the organism, with relatively little variation in the size of the individual cells.

Motility: No motility has been observed.

Staining properties: The organism stains very readily with the ordinary anilin dyes and is Gram positive.

Spore formation: Spores are formed readily in about forty-eight to seventy-two hours. They are usually formed near the center of the rod and are almost as large as the cell. Definite rims of protoplasm are usually retained around the spores.

Cultural characteristics. Agar colonies: Medium sized, elevated, glistening, viscous colonies, showing little tendency to spread were formed rather quickly. In the course of three or four days they lose their glistening appearance owing to the formation of a scum over the surface. Later the colonies seem to dry out leaving only the dry wrinkled scum, which is easily scraped from the agar

Agar slant: The growth resembles that of the agar colonies very closely. At first it is elevated, glistening and viscous and later becomes dry, grayish and wrinkled.

Agar stab: There is a small slightly spreading growth on top with slight granular beaded growth along the line of inoculation.

Gelatin colonies: Small glistening colonies are formed in cup-like depressions, due to the rapid liquefaction of the gelatin.

Gelatin stab: Liquefaction is very rapid, being at first funnel shaped. Complete liquefaction with the formation of a heavy scum occurs later.

Bouillon: A tenacious scum is formed. Slight turbidity is noticed at first, but later the media settles clear.

Potato streak: Growth is at first glistening, elevated and viscous, later becoming dry, granular and wrinkled.

Litmus milk: The milk is peptonized rather quickly, leaving a clear liquid with little change of acidity.

Fermentation tubes. Dextrose: No gas is formed but an acid reaction is produced. A heavy scum is formed at the surface with no growth in the closed arm of the tube.

Saccharose: The growth and reaction is the same as with dextrose.

Lactose: The characteristics of growth are the same as with dextrose and saccharose, but very little or no acidity is produced.

The description of this organism agrees in practically every respect with the Bacillus Panis, Migula 1900 described by Lawrence and Laubach (1).

2. The effect of heat on the organism

In order to study the resistance of this organism towards heat, sterile tubes of fresh skim milk were inoculated with a pure culture of the organism. These were then incubated until active with spore formation as evidenced by a suspension under the microscope. A set of tubes were then autoclaved for 3, 5, 8, 10 and 15 minutes respectively at 15 pounds pressure, (250° F.). All conditions, such as reaching and maintaining the necessary temperature, and treatment after the expiration of the time limit, were made as uniform as possible. Each tube was plated in triplicate on agar media both before and after autoclaving.

The following table shows the results obtained for the respective time intervals.

TABLE 1

BEFORE AUTOCLAVING	TIME	TEMPERATURE	AFTER AUTOCLAVING
colonies per cc.	*minutes*	*°F.*	*colonies per cc.*
25,200,000	3	250	42,000
22,000,000	5	250	14,500
28,700,000	8	250	560
27,500,000	10	250	None
33,400,000	15	250	None

3. Chemical study

In the study of the chemical action produced by this organism on milk proteins we were chiefly concerned with the cleavage products produced. By the use of different precipitants it is

possible to separate the complex from the less complex hydrolized products of protein degradation into reasonably well defined fractions and if the operation is conducted under like conditions these fractions must give a reasonably accurate and consistent result of the progress of the chemical changes. The fractions which seemed the most important were, the production of ammonia, peptones and the less complex protein units, the amino acids. By the use of saturated solution of zinc sulphate and phosphotungstic acid as precipitants, peptones and amino acids can be estimated.

METHOD OF PROCEDURE

Lots of 250 cc. sterilized milk were inoculated with the organism and incubated at 37°C. for 15, 30 and 45 days. After the respective periods of incubation 50 cc. of the media was aerated according to the Folin method for the determination of ammonia. After aerating for eight hours the liquid was transferred to flasks and diluted to 100 cc. From this dilution aliquots of 20 cc. were transferred to beakers, neutralized with sulphuric acid and the proteins precipitated with saturated solution of zinc sulphate and phosphotungstic acid.

Precipitation with zinc sulphate. To 20 cc. of the above dilution sufficient dilute sulphuric acid was added to make it distinctly acid to methyl red. The solution was slightly warmed and chemically pure zinc sulphate added to saturation. A portion of the zinc sulphate crystalized when the solution was cooled to room temperature. After standing for twenty-four hours the solution was filtered and the nitrogen determined in the filtrate representing nitrogen not precipitated by zinc sulphate.

Precipitation with phosphotungstic acid. To 20 cc. of the neutralized solution sufficient sulphuric acid was added to bring the acidity to 5 per cent. To this 20 cc. of a 5 per cent phosphotungstic acid solution was added and after standing for twenty-four hours the solution was filtered and the nitrogen determined in the filtrate, representing the nitrogen not precipitated by phosphotungstic acid.

Acidity. The acidity was determined by titrating 20 cc. of the medium with N/10 NaOH and expressed as lactic acid.

Ammonia. The ammonia was determined by the Folin aeration method and expressed as ammonia nitrogen.

Table 2 shows the chemical changes brought about by this organism when grown in sterile milk. The results for the nitrogen fraction are based on the total nitrogen present in the milk and the acidity expressed as lactic acid.

TABLE 2

Showing the acidity, ammonia nitrogen, nitrogen not precipitated by phosphotungstic acid and saturated solution of zinc sulphate

INCUBATION	ACIDITY	AMMONIA NITROGEN	NITROGEN NOT PRECIPITATED BY ZINC SULPHATE	NITROGEN NOT PRECIPITATED BY PHOSPHOTUNGSTIC ACID	NITROGEN AS PEPTONES
days	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
15	0.297	4.56	39.67	20.76	18.71
30	0.517	5.44	46.15	26.40	19.73
45	0.540	5.53	46.59	25.75	20.74
Blank	0.215	0.48	1.84	0.92	0.92

ACTION OF THE ENZYMES

The nature of the organism, and its activity on protein suggested the possibility of the presence of proteolytic enzyme or enzymes. It was the aim to study the secreted enzymes or exoenzymes which, owing to their filterability may be separated from foreign matter and obtained in an active state.

Flasks containing 250 cc. of sterile milk were inoculated with the organism and incubated at 37°C. for thirty-three and sixty days. At the end of the respective periods of incubation, a portion of the liquid was filtered through a Berkfeld filter. To prove the absence of organisms or spores plate cultures were made. Only in a few instances was there any contamination.

To test the activity of the enzymes obtained from the Berkfeld filter a 2 per cent solution of casein and egg albumin was prepared as follows: 2 grams each of casein and egg-albumin were added separately to 100 cc. of distilled water and sterilized. Plate cultures were here also made to prove the absence of organisms. To each flask containing the sterile proteins 10 cc. of the filtrate, obtained from the media were added and digested from

three to six days at a temperature of 37°C. Digestion was made in neutral (phenolphthalein), 0.2 per cent acid (hydrochloric acid) and 0.2 per cent basic (sodium carbonate) solution.

TABLE 3

Showing the action of the enzymes on casein, the nitrogen not precipitated by zinc sulphate, phosphotungstic acid and the peptones

INCUBATION	DIGESTION	REACTION	NITROGEN NOT PRECIPITATED BY ZINC SULPHATE	NITROGEN NOT PRECIPITATED BY PHOSPHOTUNGSTIC ACID	NITROGEN AS PEPTONES
days	*days*		*per cent*	*per cent*	*per cent*
33	3	Neutral	60.75	25.35	35.40
33	3	0.2 per cent acid	16.55	5.10	11.45
33	3	0.2 per cent basic	38.85	14.00	24.85
60	3	Neutral	62.5	31.7	30.80
60	3	0.2 per cent acid	20.00	7.6	12.40
60	3	0.2 per cent basic	37.20	9.85	27.35
60	6	Neutral	89.65	47.85	41.80
60	6	0.2 per cent acid	16.75	8.00	8.75
60	6	0.2 per cent basic	78.75	40.10	38.65

TABLE 4

Showing the action of the enzymes on egg albumen, the nitrogen not precipitated by zinc sulphate, phosphotungstic acid and peptones

INCUBATION	DIGESTION	REACTION	NITROGEN NOT PRECIPITATED BY ZINC SULPHATE	NITROGEN NOT PRECIPITATED BY PHOSPHOTUNGSTIC ACID	NITROGEN AS PEPTONES
days	*days*		*per cent*	*per cent*	*per cent*
33	3	Neutral	44.30	15.80	28.50
33	3	0.2 per cent acid	19.00	6.85	12.15
33	3	0.2 per cent basic	34.10	15.15	18.95
60	3	Neutral	50.10	24.50	25.60
60	3	0.2 per cent acid	27.45	10.10	17.35
60	3	0.2 per cent basic	31.75	10.20	21.55
60	6	Neutral	81.50	46.60	34.90
60	6	0.2 per cent acid	22.70	10.95	11.75
60	6	0.2 per cent basic	48.55	22.55	26.00

At the time expiration the enzyme action was determined by estimating the nitrogen not precipitated by zinc sulphate and phosphotungstic acid.

Tables 3 and 4 show the proteolytic action of the enzyme. The per cent nitrogen is based on total nitrogen.

DISCUSSION

From table 2 it is seen that this organism produces rapidly a large quantity of peptones and lower complex nitrogenous compounds. The excessive peptonizing function of this organism may be the primary cause of the bitterness. It is not impossible that the cleavage products produced by this organism differ in their chemical aggregation from that produced by other active peptonizing organism. This bitterness in evaporated milk has been observed by other investigators, namely, O. F. Hunziker (Condensed Milk, 1st edition, pp. 172–174) and more recently by B. W. Hammer (Studies in Abnormal Evaporated Milk 1919). The increase in acidity during the period of fifteen days incubation was very slight, and this is in agreement with that condition found in the bitter evaporated milk. The production of ammonia increased during the period of incubation from 0.48 to 5.53 per cent. This increase also emphasizes the proteolytic activity of this organism, which by some investigators is considered an index in determining the rate and degree of protein katabolism.

SUMMARY

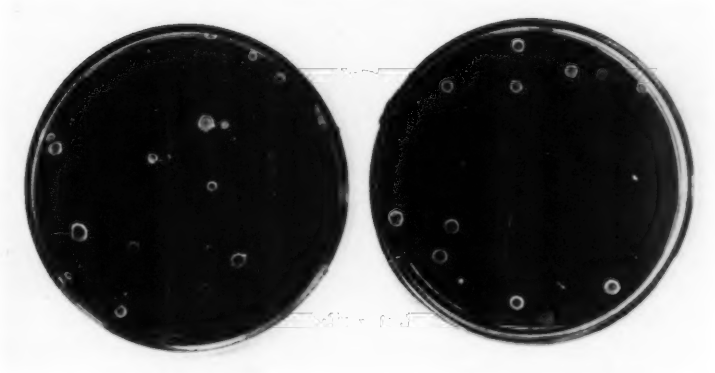
1 From the results of the bacteriological study the organism agrees morphologically and culturally with Bacillus panis migula, described by Lawrence and Laubach.

2. The thermal death point of this organism lies between eight to ten minutes exposure to 250° F. under steam pressure.

3. The substance secreted by this organism is proteolytically active, producing both peptones and amino acids. The results of the action on neutral, acid and basic substrate indicate the presence of more than one specific enzyme.

REFERENCES

(1) Lawrence and Laubach: Studies on aerobic spore-bearing non-pathogenic bactera. Jour. Bacteriol, i, 493.



PHOTOGRAPH OF THE ORGANISM STUDIED, FROM A SIXTY-HOUR PLATE CULTURE

THE EFFECT OF PASTEURIZATION ON THE NUMBER OF BACTERIA IN MILK WHEN THIS IS DETERMINED BY THE DIRECT MICROSCOPIC COUNT[1]

E. G. HASTINGS AND AUDREY DAVENPORT

From the Department of Agricultural Bacteriology, University of Wisconsin, Madison

It has been pointed out in a previous paper (1) that in the examination of milk it is desirable to obtain such information as will permit the analyst to determine as far as possible the conditions under which the milk was produced, and also to judge of its future, or keeping quality. It is obvious that in the case of pasteurized milk, any method which involves the growth of bacteria can give no indication concerning the history of the milk previous to heating. It has been thought that the direct microscopic determination of the number of bacteria did not possess the above limitation and could therefore be used more successfully in the examination of pasteurized milk than could any other method.

It is a well known fact that many bacteria are so changed on heating as not to be detected in the microscopic examination of stained preparations. The use as a culture medium of milk which contained such a number of bacteria that they were easily demonstrable with the microscope, entails no disadvantages in the subsequent examination of the pure cultures grown therein. In the heating, incident to sterilization, the cells are so changed that they can not be found with the microscope. The magnitude of the effect of lower temperatures such as are used in the pasteurization of market milk is unknown. It has been mentioned by a number of workers that the dead cells do not possess the same staining properties as the living cells, when preparations are made from milk before and after pasteurization. Kufferath (2) in a discussion of the methods of determining bac-

[1] Published with the permission of the Director of the Wisconsin Experiment Station.

teria in milk refers to the examination of stained preparations and states that dead bacteria do not stain, but that their presence is made evident by the fact that they appear in the film as clear areas in the back ground of stained casein, as do the cells in a preparation made with India ink according to the method of Burri. He states that an idea of the number of bacteria present before heating can be obtained by noting the clear areas.

Again it has been assumed by some that the heating does not change the staining properties of the cells and that therefore the direct microscopic method gives the same information in regard to a sample of milk, irrespective of whether it is applied before or after pasteurization. The following statements are taken from an article recently published (3).

> A microscopic count of pasteurized milk will show exactly what a similar count would show in raw milk—namely the number of bacteria which have gained access to milk during its production and delivery and the amount of development through growth and multiplication. . . . . The direct microscopic method of counting bacteria, revealing the living as well as the dead bacteria, enables us to put pasteurization in its proper place in the scheme of milk control and to proceed with our enforcement of bacterial standards with a success not allowed with the plate count.

For the purpose of determining the effect of pasteurization on the staining properties of bacteria in the direct microscopic method of milk examination, a number of milks were pasteurized in the laboratory at 145° F. for thirty minutes. The milks were cooled at once, and stored at about 50° F. Microscopic preparations were made from the milk immediately before pasteurization, and at varying intervals thereafter. The method of staining was kept uniform throughout the staining of any series of samples.

It is probable that the effect of heating on the number of bacteria losing their staining properties will vary from sample to sample; certain bacteria are probably more affected than others. The tubercle bacillus in broth stains as well after pro-

TABLE 1

The comparative percentage of the bacteria in raw milk that can be detected with the microscope at varying intervals after pasteurization at 145°F. for thirty minutes

	SAMPLE															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Raw.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Immediately after pasteurization..	60	30	77	30	39	60	25	18	83	24	75	50	43	56	50	69
Six hours after pasteurization..	50	8	111	30	13	37	18	27	21	4	25					
Twenty-four hours after pasteurization.....		26	122	10	39	46	12	27	100+	100+	100+	20	20	11	6	3
Forty-eight hours after pasteurization.....	25	30	166	100+	100+	94	100+	100+				30	20	9	6	25

longed heating at 212° F. as do the same cultures in which the live cells are present. Since different kinds of bacteria will react differently when the milk in which they are present is heated, no uniformity in results would be obtained in the examination of a series of milks that vary qualitatively in their bacterial content.

In the work here reported market milks were used. The technique of staining was that suggested by Breed. The per-

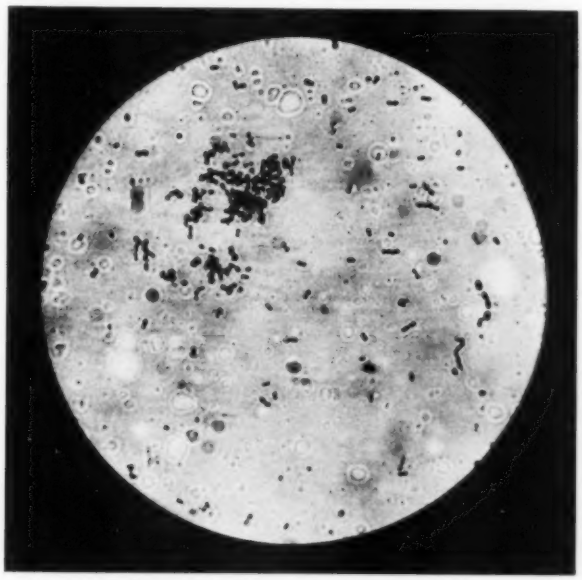


FIG. 1. A PREPARATION FROM RAW MILK

Many lactic acid bacteria are visible.

sonal factor has been eliminated by the fact that a number of individuals, working at different times, were concerned in obtaining the results reported. Approximately a hundred samples of milks, taken at various times of the year, have been examined. A detailed count of the bacteria has been made in a number of samples and the data are reported in table 1. The preparations made from the remainder of the samples were not counted; they

were, however, examined with sufficient care to determine whether the heating had had any effect on the staining of the bacteria. In practically every instance there has been a more or less marked decrease in the number of cells that could be detected. The data given in table 1 are to be considered as typical of all. For purposes of comparison the number of cells per unit volume of the raw milk is expressed as 100, the number found in the examinations made after the pasteurization, as percentages of 100.

From table 1 it is to be noted that the percentage reduction varies from sample to sample. Sample 3 in no examination revealed less than 77 per cent as many cells as were present in the raw milk; and in sample 16 only 3 per cent as many bacteria were found twenty-four hours after pasteurization as were noted in the raw milk. It is believed that these percentages represent the probable limits of the effect of the pasteurizing temperature on the number of bacteria in milk as shown by the direct microscopic method. Thirteen out of the sixteen samples showed between 10 and 30 per cent as many bacteria after pasteurization as in the raw milk, and these reductions probably represent the average that will be noted in practice. In two out of the 16 samples reported in table 1, the minimum number of bacteria was found immediately after pasteurization; in six samples the minimum number, at the sixth hour; in five, at the twenty-fourth hour; and in three, at the forty-eighth hour.

The bacteria that have not been killed in pasteurization will begin to grow when the milk is stored, and sooner or later, the number of cells in the pasteurized milk will exceed the number in the raw milk. The rapidity with which this will occur will depend on the temperature of storage and the kind of bacteria.

In table 1 the expression 100+ signifies that growth had occurred and the number of bacteria was much in excess of that in the raw milk.

Pasteurization of milk inoculated with pure cultures gave results similar to those with naturally inoculated milks. The procedure for this was as follows: Portions of fresh whole milk of a low bacterial content were inoculated with a pure culture of

the desired organism, which had been previously cultivated in sterilized milk, with frequent transfers, in order to become accommodated to this medium. These milk cultures were seeded separately into raw milk in such amounts that the bacteria were fairly numerous on a Breed plate. Stained prepara-

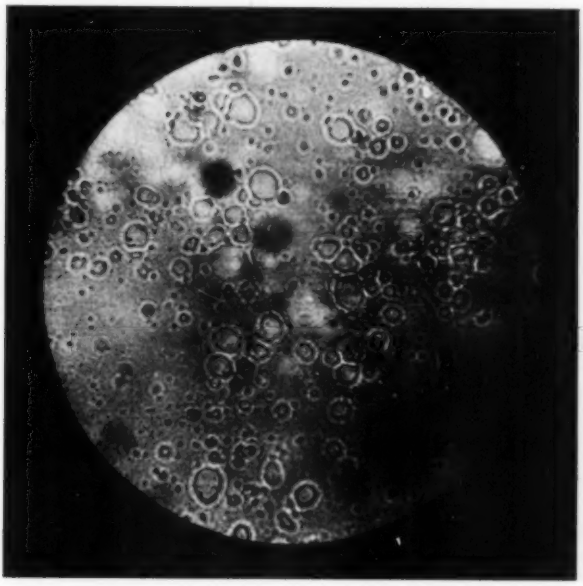


FIG. 2. A PREPARATION MADE FROM THE SAME MILK, PASTEURIZED

The milk had been stored at 50° F. for 24 hours after pasteurization when this preparation was made. The photograph shows fewer bacteria than was the actual case, as the faintly stained cells did not give sufficient contrast to be photographed.

tions were made immediately from these milks, after which they were pasteurized, cooled, and stained again in the same manner. They were then stored in the ice box, and preparations were made again at the end of twenty-four and forty-eight hours. The results are listed as follows:

Name of organism	*After 24 hours*
B. coli.....	No apparent change in staining or in number of cells
Staphylococcus pyogenes aureus.....	No apparent change in staining or in number of cells
Streptococcus pyogenes.	Cells unevenly stained—some very faint—decrease in number
Bact. lactis acidi (1)....	Cells unevenly and faintly stained—marked decrease in number
Bact. lactis acidi (2)....	Cells unevenly and faintly stained—marked decrease in number
Micrococcus.....	Cells faintly stained—decrease in number
Bact. bulgaricum.....	Cells faintly stained—no apparent decrease in number
B. anthracis.....	Only an occasional cell—only faintly stained
B. subtilis.....	No cells stained

Detailed counts were not made of the stained preparations of these cultures except of that of the micrococcus culture, and this was done because it could not be definitely told from observations whether there had been a decrease or not. The cells of this organism are unusually large and because of their size, although stained very faintly, could be counted, whereas a smaller cell would probably not have been detected. However, only 75 per cent as many cells could be found in the preparations made from the heated milk cultures as were present in the unheated. The most decided decrease was noted with B. subtilis and B. anthracis. No cells at all took the stain in the subtilis preparation, and only an occasional one, in the anthrax, after twenty-four hours storage; and indications of this disintegration of these cells were evident in the preparations made immediately after pasteurization, where the failure to take the stain but poorly was very noticeable. Stained preparations of the other cultures showed about the same average decrease as was noted with the market milks. While it is reported above that no apparent decrease was obtained with B. coli and Staphylococcus pyogenes aureus, it is possible that had these preparations been subjected to a careful count, a decrease might have been detected.

The observation of Kufferath, that the dead bacteria in heated milk appear as clear areas against a stained background was never noted in any of the numerous preparations which were made of heated milks, either of a high bacterial content or of milks which had been inoculated with pure cultures of representative milk organisms. The degree to which the bacteria vary in their staining properties after heating was from a normal color to that which was barely perceptible, which differences no doubt were caused by the type of organisms present. Staining within these limits even showed considerable variation; some of the cells were faintly but evenly stained, some showed decidedly uneven staining, especially noticeable in the chains and clumps of cells, but when no stain at all was taken this was evidenced only by a decrease in number and never by unstained areas in the shape of bacterial cells.

The conclusion that must be drawn from the data presented, and which is confirmed by the results not here reported is that a direct microscopic count of bacteria in pasteurized milk gives a very imperfect picture of the bacterial content of the same milk before pasteurization, the number of bacteria revealed may not be over 3 per cent of the number in the raw milk.

REFERENCES

(1) Hastings, E. G.: The comparative value of quantitative and qualitative bacteriological methods as applied to milk, with especial consideration of the methylene blue reduction test. Jour. Dairy Sci., ii, 293–311, 1919.

(2) Kufferath, H.: Le control bactériologique et hygiénique des laits. Methods émployees et appréciation dse résultats. Ann. de l'Inst. Pasteur, 1919, xxxiii, 462–483.

(3) Werner, Percy: Microscopic count of bacteria. Its value in grading pasteurized milk. Hoard's Dairyman, May 7, 1920.

IS ROPY MILK BECOMING A MORE SERIOUS DAIRY TROUBLE

H. A. HARDING AND M. J. PRUCHA

University of Illinois, Urbana, Illinois

Ropy milk is an old dairy trouble, and outbreaks of it are brought to the attention of the Dairy Department every year. There seems to be some basis for the feeling that this trouble is becoming more common, and this was emphasized the past season by encountering an outbreak which involved more than a hundred farms and presented the general picture of an epidemic. As both the causal organism and the epidemic nature of this outbreak were somewhat unusual, it seemed desirable to bring the matter to the attention of the dairy industry.

In presenting the details of this epidemic, the authors have drawn freely upon the observations and experiences of men in the milk industry, particularly upon certain of these men who are well trained in dairy bacteriology. It would be a pleasure to make more detailed and specific acknowledgment of these contributions were it not for the expressed wish of the commercial firms involved that no mention of their companies or of their men appear in the publication.

While both authors were located at the New York Agricultural Experiment Station, they made fairly extensive observations in connection with outbreaks of ropy milk; isolating and studying the causal organism in a number of cases. Through the kindness of the Director, W. H. Jordan, and Dr. R. S. Breed, the notes of these observations and some made by Mr. G. L. Ruehle have been placed at our disposal, and have been used in connection with this article. Grateful acknowledgment of this kindness is gladly given.

WHAT IS ROPY MILK

The term ropy or slimy is applied to milk which has become noticeably more viscous than ordinary milk. When this ropiness is only slightly developed, it is ordinarily overlooked. It is

sometimes noticed from the fact that the milk pours more slowly, or because the last portion drips from the container with the formation of an evident thread of milk.

Where the viscosity is more pronounced, the milk may be drawn out by means of a fork or similar object into threads. In extreme cases these threads may be fine and silky, and more than a foot long, though more frequently they break when only an inch or less in length.

In extreme cases, the milk takes on almost the consistency of a sticky, stiff dough, and a cup of it may be inverted without the milk being spilled.

Ropy milk should not be confused with the results of garget. Garget is an inflamed condition of the udder of the cow, and milk as it comes from such inflamed udders frequently contains white masses or strings of coagulated material. Milk which becomes ropy, on the other hand, comes from healthy udders and is normal when drawn, but the ropiness may appear at any time after twelve hours.

There are at least three common and distinct types of ropy milk: (1) the ropiness produced in milk drinks by the Bulgarian bacillus, (2) the ropiness in starter for butter making, resulting from the degeneration of the starter culture, and (3) the ropiness which appears in sweet milk.

The ropiness with which this publication is primarily concerned makes trouble in connection with city milk. It appears in sweet, well cared for milk, and ordinarily as soon as the milk begins to sour, the viscosity disappears. Moreover, this ropiness in sweet milk develops most markedly at the surface in contact with the air, and rarely appears unless the milk is kept relatively cold. When the milk is held at higher temperatures, acid develops and destroys the viscosity.

WHY IS ROPY MILK OBJECTIONABLE

With milk, as with other foods, custom is a large factor in establishing market demands. There is no question but that our retail milk trade calls for a sweet milk of normal consistency and taste. While the growth of the ropy milk germs ordinarily

produces little change in the taste of the milk, these organisms do change its consistency so noticeably as to arouse the suspicions of the consumer.

The agitation of recent years for a milk of low germ content has made the consumer very suspicious of any evidence of germ growth in milk, and doubly so of unusual appearances.

While there is no evidence nor any reason to believe that the growth of the ropy milk organisms is in any way harmful to the consumer, such milk is not acceptable to the American consuming public, and accordingly is neither profitable nor desirable in the city milk supply.

HISTORICAL

Among nomads, milk is either consumed at once, or is soured so promptly that there is little opportunity for ropiness to appear in the sweet milk. When dairymen adopted a fixed abode and milk soured more slowly, there was a better chance to observe ropiness. There is naturally no record of its first appearance, but the wide-spread use of sweet, curdled, viscous milk by the Scandinavians, the use of viscous whey in cheese making by the Hollanders, and the prevalence of viscous, sour milk beverages among the Turks, Armenians, and their neighbors, suggest that next to the souring of milk, its increase in viscosity is its most common change.

The earliest attempts at a scientific explanation of this ropiness were made by chemists but probably the first observations of the connection between germ life and these changes in milk were made by Lister (1) in 1873. Another early observation of the connection between germ life and the production of ropy milk is that of A. Schmidt (2) in 1883. His reference to this dairy trouble suggests that in Germany it was then well known, and was the occasion of considerable economic loss. While the work of Schmidt did not include the isolation and study of the causal organism, his tests of the readiness with which the ropiness was transferred to sound milk by the addition of a few drops of the ropy milk, and later likewise transferred from this to a second sample of sound milk, made plain the contagious nature of the trouble.

In 1889 there appeared at short intervals in the Milch Zeitung an article by Adametz (3) describing Bacillus lactis viscosus as the cause of ropiness in sweet milk, and one by Weigmann (4) describing, but not naming, the organism causing viscosity in sour whey. A number of organisms have been isolated, considered as new, and named in connection with the development of ropiness in milk and dairy products. Of the outbreaks in city milk supplies in this country studied by Marshall (5), Ward (6), Cole and Hadley (7), Buchanan and Hammer (8), and Harding and Prucha (9), the causal organisms seem to be identical with, or closely related to Bacillus lactis viscosus, Adametz. The points at which organisms producing ropy milk most commonly differ from the original description of Bacillus lactis viscosus are in the matter of acid and gas formation. The observations at hand suggest that if a sufficiently large number of cultures were examined, it might be possible to arrange a fairly continuous series of cultures, otherwise quite similar, but differing in that at one extreme the milk becomes slightly alkaline, while at the other the milk becomes distinctly acid. This is all the more striking in view of the fact that the alkali-producing and neutral forms are evidently sharply inhibited in milk by the formation of acid by the ordinary milk flora.

These cultures quite generally attack milk sugar and some other sugars, and in some cases appreciable quantities of gas are produced. Apparently this group of ropy milk organisms offers good material for a critical study of the validity of acid and gas formation as a basis for the separation of species.

THE EPIDEMIC

About the middle of June, 1919, complaints of ropy milk from customers of a large dairy company led to observations at the bottling plant handling this portion of its supply. Ropy milk is not an uncommon experience in connection with the city milk trade and when it appears a prompt study of the source of supply usually shows that milk infected with ropy organisms is being furnished by one or two farms. Since more or less of this trouble

appears every season, its treatment has become practically a routine matter.

In the present instance, samples from each patron's milk were collected in well steamed bottles as the cans were being emptied, and these bottles, capped or stoppered with cotton, were held at low temperature and observed for the development of ropiness.

Unless the infection is fairly heavy, the ropiness will rarely be evident before twenty-four hours, and may not appear before forty-eight hours. Where the germs are fairly abundant, the entire upper surface of the cream becomes noticeably viscous. Examinations are best made with a small bent platinum wire which is heated to redness and cooled before the examination of each bottle, so as to prevent the transfer of germs from one bottle to the next. When this wire is thrust below the surface of the cream and is withdrawn, the viscous milk is drawn out into a thread the length and thickness of which vary with the degree of ropiness. In making such examinations of milk in bottles which have been stoppered with cotton, care should be exercised not to be misled by the presence in the milk of cotton fibers. When such a fiber is caught by the wire, it often closely resembles a thread of ropy milk. Where such a wire is lacking, wooden toothpicks or forks may be used. However, unless a fresh one is used for each bottle, examinations on succeeding days may lead to wrong conclusions because of the transfer of germs from one bottle to another.

Where the infection is not abundant, the ropiness of the cream may be confined to small islands or even to very small points on the surface. At these points there is evidently the development of colonies of the germs causing the trouble. The experienced observer can often locate these points of ropiness by observing the presence of what appears to be small drops of fat in the cream. In many cases the milk surrounding these drops of fat is very ropy. On the other hand, in an occasional bottle these drops are evident and the milk is not ropy, while in many cases the milk is ropy without the presence of these drops of fat. While the relation of these drops of fat to the germs causing the trouble is not entirely clear, the connection between these drops and the ropiness is too regular to be a mere accident.

Samples were taken and examined in this way from the milk of each of the 140 patrons bringing milk to the bottling plant in question, and ropiness was noted one or more times in samples from 116 of these farms. Late in the season when a neighboring cheese factory closed and a number of its patrons transferred to the bottling plant, they also were found to be bringing the ropy organisms. Inquiries in the community in a few cases where a cow was kept by a family who was not otherwise conconnected with the dairy business showed that here, too, they were having trouble with ropy milk. In short it appeared that here was a community-wide epidemic of ropy milk, which not only included the larger part of the patrons of the bottling plant, but also included people not directly connected with the milk shipping industry.

OBSERVATIONS ON FARMS

The finding of ropy milk organisms in the milk as delivered at the bottling plant was followed by a collection of samples at the farms.

These samples ordinarily showed the presence of the ropy organisms in the utensils and in many cases also showed that they were present in the water in the cooling tank.

The observations made at one farm are sufficiently important to deserve special mention. At this farm the germs were repeatedly shown to be present on the utensils and in the water of the cooling tank. From the cooling tank the water flowed to the stock watering tank located in the barn yard, and the presence of the ropy milk germs was repeatedly demonstrated in the water from the stock tank.

The stock tank overflowed and leaked into the barn yard forming considerable mud through which the cows came to drink.

In drinking, the cows rubbed against the wet sides of the tank, and their coats also became moistened by the noses of their companions. Some mud also got upon their coats.

On two different occasions, material collected from the flank and udder of these cows and put into sterile milk produced characteristic ropiness indicating the presence of the ropy milk

germs. Both of these tests were made by the bacteriologist of the milk company. At one of the tests, one of the authors (H.) was present and observed the conditions of the barn yard and the details of the test, and he sees no reason to doubt that under these conditions the ropy germs were present on the coat of the cow and from it could have been transferred to the milk.

METHOD OF DISTRIBUTION

Finding this ropy milk organism throughout the milk of the community naturally raises the question as to its method of distribution.

The most evident point of contact among the farms supplying milk to the bottling plant is the can-washing vat at the plant. A can bringing milk infected with the ropy milk organism adds to this washing vat its quota of these organisms, some of which will be transferred to the cans subsequently washed in this same solution. As a check on the spread of germs in this way, the cans and covers were regularly passed over steam and drying jets. However, this latter process, as actually carried on, did not produce sterile cans, and the treatment of the can covers was even less efficient. The drying process likewise did not result in dry cans, and the germs surviving the steaming had an opportunity to multiply before the cans were again filled with milk. Under such circumstances it is evident that ropy milk germs might spread among the patrons of the milk plant. On the other hand, such conditions are so common among milk plants as to be fairly typical. Ropy milk appears almost every year in the supply brought to each bottling plant, and this is the first wide-spread distribution of this kind which has been reported, although this milk trouble has been known for at least a century. If the can-washing vat was the avenue of distribution, it is hard to understand why this wide-spread dissemination should be limited to this particular milk plant, unless the conditions at this plant were unusually favorable for such spread, or the organism in question was one of unusual vitality.

Everything which could be found in connection with the plant suggested more than usual care in manipulation, and rather promptly after the appearance of this trouble, the usual steaming process was supplemented by immersing the washed cans and their covers in a strong solution of bleaching powder. Careful tests of the cans after such treatment indicated that they were not then harboring the ropy milk germs. Notwithstanding this careful treatment of the cans, which was continued for some months, the trouble continued to appear among the farms. The possibility of infection at the can-washing vat will in no wise account for the appearance of the ropy milk among the patrons of the cheese factory, nor in the private dairies which were not connected with the cheese factory or the bottling plant.

The organism causing the trouble, while evidently a representative of the Bacterium aerogenes group, was not sufficiently different from the forms ordinarily encountered in ropy milk to explain this unusual distribution.

In the absence of an apparent avenue of distribution, the fairly common presence of Bacterium aerogenes in water supplies may be significant. The experiences of Adametz led him to stress water supplies as sources of ropy milk germs, and similar views were held by Ward, but in the last two decades attention has apparently drifted away from the possibility of infection through this channel. It is unfortunate that the conditions in connection with this outbreak were such as to preclude a careful study of the water flora and its relation to this trouble, though samples of the water in which the cans of milk were being cooled on farms furnishing ropy milk, in many cases, showed the presence of the ropy milk organisms. It is true that their presence in this water might be explained on the supposition that they were brought into the cooling tanks on the infected cans, but the well known ability of these germs to live in water calls for a more careful study of the relation of the water flora to the spread of ropy milk.

THE CAUSAL ORGANISM

The germs connected with the different forms of ropy milk have been described in detail by Buchanan and Hammer. The one associated with this outbreak was a short, non-motile, encapsulated rod which did not form spores, but attacked dextrose, lactose, and saccharose with the formation of acid and gas. In milk at 20°C., there was a marked increase in viscosity within twenty-four hours, together with a slow formation of acid which later became sufficient to curdle the milk. As the acid increased, the viscosity decreased. This organism is evidently a member of the Bacterium aerogenes group.

While this organism is by no means unknown in connection with this trouble in milk, it is evidently not the ordinary form producing ropiness in sweet milk, since it was found in only one of ten recent outbreaks in the country tributary to Chicago, from which cultures have been studied by the authors, and it occurred only once among eight cultures isolated and studied by the authors between 1904 and 1908 at the New York Agricultural Experiment Station. It should, however, be noted that Eckles is reported to have found representatives of this group fairly common in connection with outbreaks in Missouri (10).

RESISTANCE TO HEAT

In as much as this outbreak occurred in connection with a milk supply which was regularly pasteurized, the ability of the organism to withstand heat was a matter of considerable importance.

As ordinarily understood, the thermal death point is the temperature at which a twenty-four hour culture grown on agar slope, suspended in bouillon, and filtered through paper to remove masses of culture is completely destroyed on ten minutes exposure. There is some difficulty in accurately measuring the ten-minute exposure, because of the time required for the temperature to pass through the wall of the container, and to heat the bouillon in which the culture is suspended. The first

loss of time can be reduced to a minimum by the use of Sternberg bulbs with a capacity of 8 to 12 cc., which can be blown from glass tubing and sealed while hot. On breaking the capillary end below the surface of the bouillon, 5 to 7 cc. of the latter will be drawn into the bulb. If the capillary tube is again sealed, the bulb containing the culture may be completely submerged. The extremely thin walls offer little resistance to the passage of heat, and the small volume of fluid in the partially filled bulb quickly acquires the desired temperature, particularly if the bulbs are submerged and agitated by a suitable device.

The thermal death point of a culture of Bacterium aerogenes (B1) from this outbreak was compared with that of a culture of Bacillus lactis viscosus—Bacterium viscosum—(N), isolated about eighteen months earlier from an outbreak of ropy milk in the product of another large milk company.

TABLE 1

Growth after heating in bouillon to temperature for ten minutes

CULTURE	50°C.	55°C.	60°C.	65°C.
B1	+	+	−	−
N	+	−	−	−

The bulbs containing the cultures were exposed for ten minutes in triplicate at temperatures of 50°, 55°, 60°, and 65°C. After removal from the hot bath, the bulbs were promptly cooled to room temperature, and the contents of each bulb divided among three tubes of sterile skim milk. The tubes of inoculated skim milk were placed at 20°C. and observed for ropiness and other evidences of growth. The results of these observations are given in table 1.

The above results suggest that the culture of Bacterium aerogenes (B1) was somewhat more resistant to heat than was the culture of Bacterium viscosum (N). In this connection it should be remembered that the former culture had been isolated recently, while the latter had been carried for many months in the laboratory.

Because of the importance of the heat relation of the ropy milk organisms, the thermal death points of a second series of nine cultures were determined according to the method already given.

In this series the culture (B2) was a representative of the Bacterium aerogenes group, isolated quite independently from the same outbreak, and evidently a duplicate of B1. The other cultures used in this series were obtained within a few preceding months from different outbreaks of ropy milk within the Chicago territory, except the culture I which came about a year earlier from an outbreak in the University dairy. With the exception of B2, these cultures were apparently all representatives of the Bacterium viscosum group

The results of this test are given in table 2.

TABLE 2

Growth after heating in bouillon to temperature for ten minutes

CULTURE	55°C.	60°C.	65°C.
B2	+	−	−
B3	+	−*	−
B4	+	−*	−
B5	+	−	−
B6	+	−*	−
B7	+	−*	−
B8	+	−*	−
B9	+	+	−
I	−	−	−

* Indicates that one of the three Sternberg bulbs produced growth.

From the results given in table 2 it is seen that five of the nine cultures show a thermal death point at approximately 60°C., since of three bulbs of each culture simultaneously exposed to this temperature for ten minutes two failed to survive, while in the third bulb some of the germs remained alive. In the case of culture B9, germs in all three bulbs survived, while in cultures B2, and in I, all perished during the heating at this temperature.

It is also of interest to note that culture I, which had been cultivated in the laboratory for about a year, showed a distinctly lower thermal death point.

Since the temperature and time of heating used in commercial pasteurization is 140°–145° F. (60°–62.8°C.) for thirty minutes, it is difficult to understand from the above results why these germs made trouble in the pasteurized product of the milk companies.

In the established methods for thermal death point determinations, care is exercised to avoid the presence of masses of growth in the material as tested, and the test is made with bouillon through which heat passes readily. Under commercial conditions the ropy milk germs grow for some hours in the full milk, developing colony masses of growth, and full milk offers decidedly more resistance to the passage of heat than does bouillon.

Accordingly, in order to copy commercial conditions more closely, flasks of sterile whole milk were inoculated from transfers of the same cultures used in the first experiment. After standing about eighteen hours, the milk was decidedly ropy. It was then, without filtering, transferred to Sternberg bulbs, and these bulbs were exposed 10 minutes in triplicate at 55°, 60°, and 65°C. After being heated, the bulbs were cooled, the material transferred to sterile milk, held at 20°C., and observed as in the first experiment.

The results of this test are given in table 3.

TABLE 3

Growth after heating in milk to temperature for ten minutes

CULTURE	55°C.	60°C.	65°C.
B1	+	+	−
N	−	−	−

Again there is evidence that the culture of Bacterium aerogenes (B1) was distinctly better able to withstand heating than was the culture of Bacterium viscosum (N). In this case the result is in part due to the fact that B1 grew much the better in the milk, and as a result, the milk containing this culture was much more ropy at the time it was heated. Particularly in the milk containing the culture of B1, the development of the ropy germ exceeded anything which would probably occur in milk

about to be pasteurized commercially. It is therefore of interest to note that, while these germs were able to survive a heating for ten minutes at the minimum pasteurizing temperature, they did not survive a heating for ten minutes at 65°C., which is but slightly above the maximum temperature often attained in the commercial pasteurizing process.

In order to more severely test the ability of masses of bacteria to survive high temperatures, a fourth series was tested, using the same cultures. In this case transfers were grown twenty-four hours on agar slopes; the somewhat tough growth was rubbed loose with a platinum wire, and the fragmented material washed out into sterile whole milk, using about 10 cc. of water in making the transfer. The resulting suspension containing considerable masses of bacteria was put, without filtering, into Sternberg bulbs and heated in triplicate at 55°, 60°, and 65°C. These heated bulbs were cooled and tested as in the preceding series. The results are given in table 4.

TABLE 4

Growth from bacterial masses after heating to temperature for ten minutes

CULTURE	55°C.	60°C.	65°C.
B1	+	+	+
N	+	−	−

Once more a greater ability to withstand heating is shown by the culture of Bacterium aerogenes (B1). However, in this case also, the greater vigor of its growth on the agar slope is undoubtedly a factor in this result.

Comparing the results from this fourth series with those of the two preceding trials, it is seen that the increased size of the bacterial masses in the material tested measurably increases the ability of the germs to withstand brief exposures to high temperatures.

It has been shown that the thermal death point of these cultures of ropy milk organisms is approximately 60°C. (140° F.) on a ten-minute exposure, and that under commercial conditions the resistance of these germs may be measurably increased.

Accordingly, all the cultures were given a test designed to be more severe than the most extreme conditions which would occur in connection with commercial pasteurization.

Flasks of sterile whole milk were inoculated from the various cultures about eighteen hours before the test. At the time this inoculated milk was transferred into the Sternberg bulbs, a number of the flasks were extremely ropy, and some ropiness was evident in all of the flasks. Triplicate flasks were used for each germ for each period of exposure, and the effect of heating to 140° F. (60°C.) was tested at the end of ten, twenty and thirty minutes. The results of this heating were tested as in the preceding series, and the results are shown in table 5.

TABLE 5

Growth from ropy milk after heating at 140° F.

CULTURE	10 MINUTES	20 MINUTES	30 MINUTES
B1	+	+	−
B2	+	+	−
B3	−	−	−
B4	+	+	−
B5	+	+	−
B6	+	+	−
B7	+	−	−
B8	+	−	−
B9	+	+	−
N	−*	−	−
I	−	−	−

* Growth appeared in the material from one of the three bulbs.

The results given in table 5 show that two of the eleven cultures were completely destroyed after heating to 140° F. for ten minutes, and one of the other cultures was almost destroyed. Only six of these cultures survived a heating for twenty minutes, and all of the cultures were destroyed before the end of thirty minutes.

In considering the application of these results to commercial pasteurization, it should be remembered that the temperature was so controlled during the progress of this test as to vary not more than one half a degree from 140°. It should also be noted

that this test was conducted at the minimum temperature used in commercial pasteurization, while in commercial work during pasteurization much of the time the temperature of the milk is between 142° and 144° F. Furthermore, the development of the germ life in the milk used in this test had proceeded far beyond what would be encountered in commercial pasteurization, and the results given in tables 3 and 4 show that this more abundant growth increased the ability of the germs to withstand heating.

Accordingly, in the light of all these studies of the relation of the ropy milk germs to temperature, it seems clear that proper pasteurization of milk at 140°–145° for thirty minutes should destroy any ropy milk organisms which may be in the milk.

CONTROL OF THE TROUBLE

If this summary of the situation is correct, next to souring the most common change occurring in milk is the development of ropiness. Unfortunately holding milk at low temperature, which markedly checks acid development, has little restraining influence upon the development of the ropy milk organisms.

Just as sour milk is selected by many as a desirable drink, ropy milk is prized by some people as a desirable dish. However, for the city milk trade both changes are undesirable, and, therefore, it is to the advantage of the milk producer and dealer to prevent or delay both forms of change.

Where the milk is to be sold raw, the control of ropy milk is limited to preventing, as fully as possible, the ropy germs from getting into the milk. Experience has shown that the ropy organisms, when once they are introduced into a dairy, develop freely on the dairy utensils. Accordingly, when ropiness develops in connection with a given dairy, the most helpful procedure is to treat all objects coming into contact with the milk between the cow and the consumer. Where a large steam chamber is available, this treatment may take the form of live steam. Where an abundant supply of hot water is at hand, putting the utensils into hot water and bringing all parts of the utensils up

to 200° F. for a few minutes will suffice. Where both these means of treatment are lacking, recourse may be had to chemical disinfection.

A 12-ounce can of good strength bleaching powder (chlorinated lime) added to 100 gallons of water will give a powerful disinfecting solution. All pails, strainers, cloths, brushes, and other utensils which come into contact with the milk are then put into this solution and allowed to remain fifteen or twenty minutes. On removing utensils from such a solution, they should be promptly rinsed to stop the action of the chemicals.

It should be understood that this exposure to heat or to disinfectants followed by thorough washing leaves nothing on the utensils which will prevent the growth of ropy milk organisms if they find their way to the utensils after treatment. In actually carrying out such a disinfecting campaign at the farm, it occasionally happens that there is overlooked some pail, dipper, or other object which has been in contact with the ropy milk. If in connection with the handling of the milk, the germs on this one utensil spread to others, the result of the disinfection is lost and the trouble will reappear in the milk.

Where cooling tanks are used in a dairy having this trouble, the ropy germs are commonly present in the water in the tank. Accordingly, unless the tank is also disinfected, the outside of the cans will be re-seeded promptly with the ropy germs. To prevent this the cooling tank is emptied, scrubbed, and used in making the disinfecting solution described above. In such cases it is well to scrub both the tank and the interior of the milk house with the disinfecting solution.

In the actual handling of outbreaks where this work of disinfection is carefully and thoroughly done, the trouble rarely reappears. Occasionally, however, as in the case of this outbreak, there is a source of infection outside of the circle reached by this treatment, and from this source the trouble is renewed.

In the case of a company receiving milk which is to be pasteurized, the situation is somewhat different. Where the ropy milk is being furnished by one or two patrons, the treatment outlined for the dairy is usually efficient. However, when there

is an outbreak in any measure approximating the extent of the one here described, this procedure becomes expensive. It also tends in various ways to develop dissatisfaction among the patrons. Under such circumstances, it is entirely possible to handle the situation by giving attention to conditions at the milk plant.

Attention has been called to the possibility of spreading the trouble through lack of care in handling the washed cans. Every consideration in the case calls for a thorough steaming and drying of the washed cans. While increasing attention is now being given to this question at many milk plants, the present methods in most cases leave much to be desired, particularly in the drying of the cans and the can covers.

The results which have already been given show that the ropy organisms will not survive pasteurization at 140° F. for thirty minutes. Accordingly, all that is necessary in order to free the incoming milk from these germs is to be sure that the milk is all actually heated for this length of time and to this temperature. This involves careful attention to the process, particularly at the beginning and at the close of the pasteurization operations for the day.

Attention has already been called to the readiness with which the ropy germs develop upon the utensils at the dairy. They grow with equal readiness upon the utensils at the milk plant. Whenever any of them escape destruction in the pasteurizer, they may grow and make trouble. Horizontal coolers and bottlers are usually not so treated as to destroy such germs. This destruction may be best accomplished by surrounding these utensils with canvas and treating them with live steam. Milk pumps are also difficult to treat satisfactorily. The washing process should be followed by a thorough steaming of the entire milk handling system, giving particular attention to the portion between the pasteurizer and the bottle. Just before beginning operation the following morning, the entire milk line should be treated again with hot water or steam.

Attention, likewise, should be given to the milk bottles. These frequently bring the germs of ropy milk into the plant

and infect a considerable number of bottles in the washing vat. Unless the bottle washing process terminates with a treatment which brings the bottles to at least 200° F., there is a probability that these germs may develop again when the bottles are filled with milk.

Care is especially necessary in the handling of pasteurized cream held over from the preceding day which is bottled before beginning work on the milk. Where the cream is infected, the germs develop even in cold storage, and the bottling of the cream leads to a heavy infection of the bottling machinery.

When a milk plant is well seeded with the germs of ropy milk, it is quite difficult to immediately locate and destroy all of them. On the other hand, careful attention to the details of pasteurization, combined with careful steaming of all the utensils between the pasteurizer and the completion of the bottling, will at once reduce the infection to so low a point that it will cease to cause complaint among the consumers.

FACTORS INFLUENCING DISTRIBUTION

While ropiness, next to souring, is probably the most common change in milk, the souring of milk is almost universal. The development of acid hinders the development of the germs ordinarily producing ropiness in sweet milk with the result that raw milk held at room temperature practically always sours. As more careful attention to the handling of milk reduces the number of acid producing germs which are added to it, or the milk is held at a lower temperature which is relatively more favorable to the development of the ropy germs, or the acid producing germs are largely destroyed by pasteurization, the chances become more favorable for the development of the ropy germs.

However, ropiness in milk is the result of the growth in the milk of some representatives of a rather small group of germs. Even though the conditions in general are gradually becoming more favorable for the development of ropiness, it does not necessarily follow that the ropy germs will be at hand to take advantage of these improved opportunities. Little is known

regarding the places in nature where these ropy milk germs flourish, though there is some ground for believing that at times they may be normal inhabitants of water. However, the fact that this change in milk has been known in every land as far back as history goes suggests that the causal organisms are rather widely spread.

Recent observations have also developed the fact that ropy milk organisms are frequently present in small numbers in a milk supply which is quite acceptable to the consumers. In other words, ropy milk germs are more common members of the ordinary milk flora than is commonly understood at present, and objections are raised to them by the consumers, only when they become so abundant that their action on the milk becomes obvious.

It has been thought that the more frequent appearance of ropy milk is due to the development of new or more virulent ropy milk organisms. From the facts which have been here presented, it can be seen that this result can be even better explained on the basis of an improved handling of the milk which is directed against acid-producing germs, and which indirectly favors those producing ropiness.

In the case of the somewhat startling outbreak here recorded, its unusually wide distribution was probably due to some widespread natural source of infection, rather than to any unusual characteristic of the causal organism.

If the thesis here developed is correct, conditions for the development of outbreaks of ropy milk become more favorable as the milk is so handled as to reduce the tendency for it to become sour.

While there is little or no evidence that the causal organisms have taken on an increased vigor, this change in conditions will lead to more frequent outbreaks, unless steps are taken to counteract these new tendencies. Both on the farm and in the milk plant more care should be exercised in the handling of the utensils which come into contact with the milk. Where pasteurization is properly done, and the utensils at the milk plant are properly handled, an outbreak of ropy milk may be controlled, even where attention is restricted to these items.

The changing methods of milk production and handling are making it relatively easier for an outbreak of ropy milk to occur, but the increased knowledge of the growth conditions and temperature relations of the causal organisms are making it fairly easy to control such outbreaks.

REFERENCES

(1) LISTER, JOSEPH: Quart. Jour. Microscopic Sci., xiii, 380–408, 1873. (Quoted from Buchanan and Hammer.)
(2) SCHMIDT, A.: Untersuchungen uber fadenziehende Milch. Land. Versstation xxviii, 91–109, 1883.
(3) ADAMETZ, L.: Ueber einen Erreger der schleimigen Milch (Bacillus lactis viscosus). Milch-Zeitung, xviii, 941–943, 1889.
(4) WEIGMANN, H.: Der Organismus der sogennanten langen Wei. Milch Zeitung, xviii, 982–983, 1889.
(5) MARSHALL, C. E.: Ropiness in milk. Mich. Agr. Exp. Station Bul. 140, 1897.
(6) WARD, A. R.: Ropiness in milk and cream. Cornell Agr. Exp. Station Bul. 165, 1899. Also Cornell Agr. Exp. Sta. Bul. 195. 1901.
(7) COLE, L. J., AND HADLEY, P. B.: Ropy milk in Rhode Island. Rhode Island Agr. Exp. Station Bul. 136, 1909.
(8) BUCHANAN, R. E., AND HAMMER, B. W.: Slimy and ropy milk. Iowa Agr. Exp. Research Bul. 22, 1915.
(9) HARDING, H. A., AND PRUCHA, M. J.: An epidemic of ropy milk. Ill. Agr. Exp. Station Bul. 228, 1920.
(10) ECKLES: Quoted from Iowa Agr. Exp. Station Research Bul. 22, p. 268.

A COMPARISON OF THE BUTTERFAT CONTENT AND THE TOTAL SOLIDS CONTENT OF CREAMS OF VARYING RICHNESS SEPARATED FROM THE SAME SAMPLE OF MILK

B. A. STIRITZ AND O. R. OVERMAN

Department of Dairy Husbandry, University of Illinois, Urbana, Illinois

The manufacturers of ice cream for a number of years have given careful consideration to the butterfat content of cream, both from the standpoint of purchasing cream and from the standpoint of the percentage of fat in their finished product. This has been due partially to the fact that the value of the cream has been set largely by its butterfat content, and also because a minimum fat content of the finished product is set forth in legal standards. Little attention has been given to the percentage of the solids-not-fat in cream, even though the ice cream manufacturer has realized that a certain percentage was necessary to produce a good quality of the finished product. However, because of the increased cost of materials that go to make up the ice cream mix, the ice cream manufacturer has recently become keen in standardizing not only the butterfat, but the milk solids-not-fat as well.

Many analyses of milk and cream can be found in dairy literature, however very few data, if any, are available which give a comparison of the composition (fat, solids-not-fat, and total solids) of creams and the original milk from which they are separated. Various formulas have been used for estimating the amount of solids-not-fat in milk and cream, one commonly used being the pounds of milk serum (total weight of milk or cream minus the butterfat content) multiplied by 8.9 per cent. For example, using this formula there would be 6.23 per cent of solids-not-fat in 30 per cent cream.

The present investigation was carried on in order to determine the relation between creams of different fat contents obtained

from the same sample of milk; to make comparisons between the compositions of different samples of milk and cream and of creams obtained by the use of different makes of separators; and to determine whether the above stated formula is accurate enough for practical use in standardization.

Samples of milk representing four dairy breeds (Jersey, Guernsey, Ayrshire, and Holstein) and mixed milk as received at a milk plant were used, and also four different makes of separators. Normal conditions were employed in the use of the separators, i.e., the milk was separated at a temperature of 85°F., and the speed of the bowl was held at the point which the respective manufacturers recommend for maximum efficiency in separation.

The separator was adjusted to deliver a low testing cream. A sample of this cream was taken. The machine was then readjusted to deliver a higher testing cream, and a sample was taken. This procedure was repeated until four or five samples of cream—each varying in the butterfat content—were secured. These samples, along with the original sample of milk, were analyzed for butterfat by the Roese-Gottlieb method, and for total solids by the "Official Method" (using aluminum dishes). The percentage of solids-not-fat in each sample of cream and milk was determined by the difference between the total solids and the butterfat content.

The results of 71 determinations in 14 separate runs—with the source of the supply and the separator used varying—are condensed in the following tables and graphs. The separators are designated by the letters A, B, C, and D, and not by their respective trade names.

The results show that the percentage of total solids varies in direct proportion with the increase in the percentage of butterfat (fig. 1).

The percentage of solids-not-fat decreases as the butterfat content increases, but the variation is not in any definite inverse proportion. The percentage of solids-not-fat decreases very rapidly as the butterfat content increases up to 20 per cent, but it decreases less rapidly as the butterfat increases from 20 to

Results of 71 determinations in 14 separate runs—with the source of supply and the separator used varying

LOT	SEPARATOR USED	SOURCE OF SAMPLE	ORIGINAL MILK			10 TO 20 PER CENT CREAM			20 TO 30 PER CENT CREAM			30 TO 40 PER CENT CREAM			40 TO 50 PER CENT CREAM			50 TO 60 PER CENT CREAM			60 TO 70 PER CENT CREAM		
			Fat	T. S.	SNF	Fat	T. S.	SNF	Fat	T. S.	SNF	Fat	T. S.	SNF	Fat	T. S.	SNF	Fat	T. S.	SNF	Fat	T. S.	SNF
			per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	A	Mixed	4.89	14.02	9.13							30.44	36.49	6.05	46.04	51.30	5.26	50.31	55.46	5.14			
												33.30	38.86	5.56									
												39.86	45.35	5.49									
2	B	Mixed	4.76	14.12	9.36							36.11	41.87	5.76									
												38.42	43.97	5.80	40.25	45.84	5.58						
3	A	Jersey	5.66	16.19	10.53										47.38	52.39	5.01						
		Guernsey										37.54	43.95	6.41	45.29	51.05	6.75						
															44.77	50.87	6.10						
4	A	Holstein	3.42	12.39	8.97				22.63	29.04	6.40				44.47	50.61	6.14						
			5.81*	13.84	8.03				20.80	27.69	6.89				44.67	49.55	4.88						
5	B	Jersey	5.06	13.87	8.81													53.82	58.00	4.19	60.22	63.80	3.58
		Guernsey																54.28	58.28	4.01	64.69	67.59	2.90
6	B	Holstein	3.66	10.89	7.23							39.76	44.47	4.72	44.89	49.30	4.41	59.13	63.36	4.23			
																		59.46	63.68	4.23			
7	C	Holstein	3.71	13.17	9.46				28.15	33.07	4.91	38.90	43.92	5.02	43.74	48.21	4.47						
															46.24	52.51	6.28						
8	B	Jersey	5.50	14.48	9.99													56.24	60.60	4.36			
																		58.09	62.14	3.05			
																		51.07	55.86	4.79			
9	A	Mixed	4.30	13.30	9.00							36.34	41.71	5.37	44.65	49.72	5.07	51.07	56.28	5.21			
															46.64	51.46	4.82						
10	B	Ayrshire	3.40	12.40	9.00	13.02	20.10	7.08	25.56	33.76	8.20	39.89	43.22	3.33									
		Holstein										31.15	37.10	5.96									

11	B	Holstein	3.79	13.06	9.27				25.50	31.25	5.75	38.28	43.18	4.89	41.13	46.14	5.01	50.07	54.31	4.24			
12	D	Mixed	4.20	13.89	9.68	18.41	24.76	6.35				38.24	43.64	5.41	44.77	50.02	5.26						
															46.53	51.98	5.45						
13	A	Ayrshire	3.45	11.60	7.15	13.63	20.70	7.07															
		Holstein				13.71	22.29	9.58															
						13.82	21.73	7.91															
						14.05	21.66	7.61															
14	B	Holstein	4.11	14.00	8.89				25.89	31.89	6.00	39.42	44.16	4.74				51.39	56.10	4.71			
									27.06	32.43	5.37												
Average.....			4.38	13.42	9.03	14.44	21.87	7.60	25.09	31.30	6.22	36.98	42.28	5.32	44.73	50.05	5.39	54.08	58.55	4.38	62.45	65.69	3.24

* Specially standardized sample of milk from Lot 4.

Figure 1.

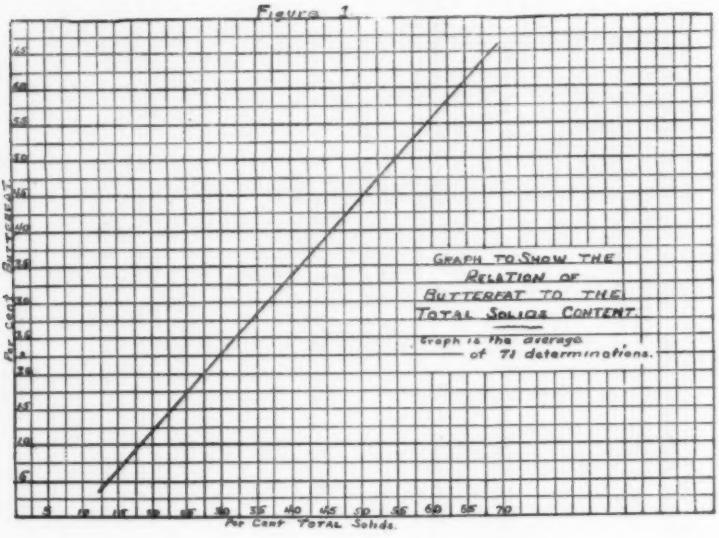
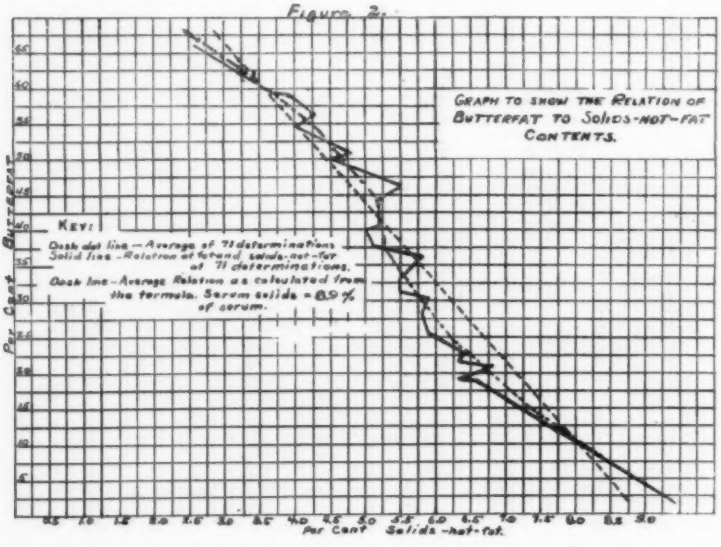

Per Cent Butterfat
Per Cent Total Solids.
Graph to Show the Relation of Butterfat to the Total Solids Content.
Graph is the average of 71 determinations.

Figure 2.


Per Cent Butterfat
Per Cent Solids-not-fat.
Graph to show the Relation of Butterfat to Solids-not-fat Contents.
Key:
Dash dot line — Average of 71 determinations
Solid line — Relation of trend solids-not-fat of 71 determinations.
Dash line — Average Relation as calculated from the formula. Serum solids = 8.9 % of serum.

45 per cent. From this point, the percentage of solids-not-fat decreases in about the same ratio with the percentage of butterfat increase, as was the case when the butterfat was increasing from 5 to 20 per cent (fig. 2).

The table shows that creams of the same butterfat content are approximately the same in their content of total solids, and of solids-not-fat regardless of the source of supply of the original milk or the separator used in the separation process. Although there is this close relationship in the case of these creams, it will be noted that the original milk of the various breeds varies with the usual marked differences. A large variation in the total solids and the solids-not-fat is shown among milks having practically the same butterfat content, but after the milks have been run through the separators, creams of practically the same butterfat content are very closely related in their content of total solids and of solids-not-fat.

The determinations show that the formula (8.9 per cent of the milk serum equals the serum solids) does not give the actual serum solids content, but can be used only to approximate the amount. The largest variation of the actual analyses from the content as calculated by the formula is 0.5 per cent. This is a large variation when one takes into consideration the fact that the solids-not-fat do not run over 6 to 7 per cent for creams which are mainly used in preparing ice cream mixes, etc., i.e., creams testing from 15 to 30 per cent butterfat. For creams of this richness, the formula figures the serum solids higher than they really are, and a material loss both financially and in the quality of the finished product may result. From the example given in the fore part of this article, a 30 per cent cream was found to contain 6.23 per cent solids-not-fat by the formula, but by chemical analyses it was found to contain 6.05 per cent, which means an error of 2.975 per cent. Thus for every hundred pounds of solids-not-fat computed by the formula, there is a loss of practically three pounds of solids-not-fat in the finished product. In the case of creams testing over 41 per cent, the chemical determinations show that the percentage of solids-not-fat (or serum solids) is larger than the amount as calculated by

the formula. For the creams testing under 41 per cent, the formula gives a higher content than is found in the cream by the analyses.

To a certain extent, the practice of considering cream as being skim milk plus the butterfat content is also erroneous. The table of analyses and the graphs show that the serum of the cream does not compare in composition to the serum of the skim milk owing to the fact that there is a variation in the rate of a decline in the amounts of water and solids-not-fat as the percentage of butterfat in the creams increases. Whether or not this is a fixed variation was not determined.

A STUDY IN BULLS

ANDREW C. McCANDLISH AND LAURENCE M. WINTERS

Animal Husbandry, Dairy Husbandry Section, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa

The high producing dairy cow of today is the result of intelligent breeding, feeding, and selection, and on these factors depends largely the future development of the dairy industry. More cows are undoubtedly needed to increase the national supply of dairy products, but, if economy of production is to receive the consideration which it deserves, better cows are of even greater importance.

It is recognized that the sire in use on a dairy farm may have a profound influence on the future usefulness of the herd and this point is being emphasized at the present time by the nation-wide campaign to promote the use of better bulls. Consequently, a study of the relative values of a few bulls may not be out of place especially as it brings out some important problems in breeding.

RÉSUMÉ OF PREVIOUS WORK

A considerable amount of work has been done to show the value of purebred bulls as demonstrated by the records of their daughters while producing under the supervision of the Breed Associations and the Experiment Stations. This work is valuable but it need not be considered here as it deals with selected populations—cows which did not come up to certain standards, set by the Breed Associations, being automatically eliminated. Work with unselected populations is more limited.

In his work with the Jersey herd at the University of Missouri Eckles (1) has shown the differences which occur in the abilities of bulls to sire daughters capable of good production.

In the Missouri work no age allowance was made but where only a limited number of records for the heifers were available they were compared with the corresponding records of their

dams. There are vast differences in the values of these bulls so far as the producing abilities of their daughters are concerned. The daughters of the best bull produced 61 per cent more butterfat than did their dams while those of the least valuable bull gave 26 per cent less fat than their dams. Some of the bulls had daughters which differed very little from their dams in producing ability.

TABLE 1

A comparison of the Jersey sires used in the University of Missouri herd

SIRE	DAMS				DAUGHTERS				INCREASE IN PRODUCTION	
	Number of cows	Number of lactations	Average production		Number of cows	Number of lactations	Average production		Milk	Fat
			Milk	Fat			Milk	Fat		
			lbs.	*lbs.*			*lbs.*	*lbs.*	*per cent*	*per cent*
Missouri Rioter	4	23	5380	234	4	26	4381	216	−19	−8
Hugorotus	11	62	4969	231	11	50	4576	245	−8	6
Lorne of Meridale	12	66	4559	231	12	67	5969	287	31	30
Missouri Rioter 3rd	3	14	4775	238	3	15	8005	384	68	61
Minette's Pedro	20	66	5321	268	20	66	5376	271	1	1
Brown Bessie's Registrar	5	8	6029	293	5	8	4295	217	−29	−26

It is reported from the Ohio Station (5) that one Holstein bull in the station herd had daughters which produced 1299 pounds more milk and 40 pounds more fat than their dams while a Jersey bull in the same herd had daughters yielding 700 pounds less milk and 45 pounds less butterfat than their dams.

Work reported by Kildee and McCandlish (2) showed that purebred sires did much in one generation to develop a herd of good producing cows from a foundation of scrubs and later results on this project by McCandlish, Gillette and Kildee (4) showed that the use of purebred sires on a scrub herd could double the milk and butterfat production in two generations.

Further interesting information was obtained in this work regarding the variations in the ability of two Guernsey bulls to sire good producing daughters. The Missouri work shows that some purebred sires are not good enough to head a purebred

herd and the Iowa results clearly demonstrate that some pure-bred sires should not even be used on scrub or grade cows. The daughters of one of the Guernsey bulls under consideration produced 35 per cent more butterfat than did their scrub dams while the daughters of the other bull produced only 2 per cent more fat than their scrub dams.

Lawritson and his co-workers (3) discussed the value of a Jersey and two Holstein bulls used at the Nebraska Station.

TABLE 2

A comparison of sires used at the Nebraska Station

SIRES	DAMS				DAUGHTERS				INCREASE IN PRODUCTION	
	Number of cows	Number of lactations	Average production		Number of cows	Number of lactations	Average production		Milk	Fat
			Milk	Fat			Milk	Fat		
			pounds	*pounds*			*pounds*	*pounds*	*per cent*	*per cent*
Jersey										
Golden Shylock.....	9	21	6,491.1	345.7	12	21	8,496.9	466.1	31	35
Holstein										
Prince Ormsby Mercedes DeKol.....	3	6	13,704.5	435.6	3	6	17,677.2	660.6	29	52
King Segis Hengerveld Vale.....	5	8	13,630.7	454.2	5	8	17,261.5	600.0	27	32

The first and second lactation periods of the daughters of these bulls were compared with the corresponding periods of their dams. For the purposes of comparison and uniformity an age allowance has been made for those records and where immature records for the dams are not available the records of the daughters have also been deleted. The records used here are therefore on a different basis than that on which they were originally reported.

In this work it was found that each of the three bulls discussed had a considerable influence in increasing the productivity of the herd.

SOURCE OF DATA

This study comprises a summary of the results obtained through the use of bulls in the purebred herds on the Iowa State College Dairy Farm since its establishment as a separate unit in 1907. Some bulls, including a few that were used for a short time only, have had but one daughter complete one or more lactation periods on the farm, and so the data concerning these have been excluded as valueless.

All normal records completed by the purebred daughters of the other bulls have been included and the records of these cows are compared with the records of their dams. Where records are of long duration only the first 360 days are considered.

TABLE 3

Percentage of mature production expected of immature heifers

AGE	PERCENTAGE OF MATURE PRODUCTION
years	
1	70
2	80
3	85
4	95

To make the records comparable an age allowance has been introduced. All records are computed to the mature—five-year old—basis and the scale of allowances for different ages is based on a study made at the Iowa Station of over 10,000 yearly records.

Unfortunately the numbers of daughters of the various bulls are in some cases not large, but some indication of the value of the bulls can be obtained from the records.

DISCUSSION OF RESULTS

The five bulls of four dairy breeds that were used in this work were evidently of different values so far as their abilities to sire good producing daughters were concerned. It is not possible to rank the bulls absolutely according to their abilities as can easily be seen from a study of the records of the two generations

TABLE 4

Summary of results with sires used at Iowa State College

SIRES	DAMS					DAUGHTERS					TOTAL INCREASE IN PRODUCTION			PERCENTAGE INCREASE IN PRODUCTION		
	Number of cows	Number of lactations	Average production			Number of cows	Number of lactations	Average production			Milk	Fat	Fat	Milk	Fat	Fat
			Milk	Fat	Fat			Milk	Fat	Fat						
			pounds	*pounds*	*per cent*			*pounds*	*pounds*	*per cent*	*pounds*	*pounds*	*per cent*	*lbs.*	*lbs.*	*per cent*
Ayrshire																
Willowmoor Robin Hood 19th	3	13	8,932.3	330.44	3.70	3	4	9,666.4	432.03	4.47	734.1	101.59	0.77	8	31	21
Guernsey																
Imp. Rouge II's Son	5	46	6,630.9	286.98	4.33	8	14	7,253.5	357.42	4.93	622.6	70.44	0.60	9	25	14
Holstein																
Spring Farm King Pontiac 8th	6	23	13,051.9	457.50	3.51	6	12	13,433.9	470.43	3.50	382.0	12.93	−0.01	3	3	0
Jersey																
Fox's Lad O'Dreamwold	3	13	7,667.9	356.30	4.65	3	7	6,005.0	290.84	4.84	−1,662.9	−65.46	0.19	−22	−18	4
Pogis 80th of Hood Farm	7	46	7,280.4	343.25	4.71	9	19	7,504.6	393.65	5.26	224.2	50.40	0.55	3	15	12

of females considered and no breed distinctions should be attempted. This is further emphasized by the fact that within one breed are two bulls, one of which produced a 15 per cent increase and the other an 18 per cent decrease in the fat production of the herd.

Three of the bulls considered were valuable as herd improvers as their daughters produced from 15 per cent to 31 per cent more butterfat than did their dams: The daughters of one produced only 3 per cent more milk and fat than did their dams so he did not work any marked improvement, but it should be remembered that the cows to which he was mated produced on the average over 100 pounds more butterfat per year than did the cows to which the other bulls were mated. The remaining bull was a detriment to the herd as his daughters produced 22 per cent less milk and 18 per cent less fat than did their dams.

It is very generally considered that milk production can be changed more rapidly than can the yield or percentage of butterfat but in the cases under consideration the reverse proved to be true as a rule.

THE INDIVIDUAL BULLS

The individual bulls do not need consideration in great detail as a general rule but it may be said that the three daughters of the Ayrshire bull, Willowmoor Robin Hood 19th, were all out of different dams and two of them exceeded their dams in producing ability while the other was of about the same capacity as her dam.

The Guernsey bull, Imp. Rouge II's Son, had eight daughters out of five different cows and on the average they produced 25 per cent more butterfat than their dams. They varied greatly in producing ability, however, the average production of the best one being 400.58 pounds, while that for the poorest was 271.79 pounds of fat. There seem to be two main reasons for this and these will be discussed later.

The daughters of the Holstein bull, Spring Farm King Pontiac 8th, were all from different cows and in five cases they were better producers than their dams.

The three daughters of the Jersey bull, Fox's Lad o'Dreamwald, were all from different cows and in each case they were poorer producers than their dams. The other Jersey bull, Pogis 80th of Hood Farm had nine daughters out of 7 cows and in all but three cases they were better producers than their dams.

INDIVIDUALITY AS A PRODUCTION DETERMINANT

The individual cow must be looked on as the unit when milk production is being considered and its great importance is emphasized by a few cases found in the present study.

From a survey of the records given in table 5 it can be seen that animals which were full sisters varied greatly in their producing ability on several occasions. The two cows 247 and 298, out of cow 97 and by Imp. Rouge II's Son were both much better producers than their dam and were quite uniform in production. When two other daughters of Imp. Rouge II's Son are considered, namely cows 225 and 267 out of cow 98, a quite different set of conditions are found as cow 225 produced the same amount of fat and 14 per cent less milk than her dam while cow 267 produced 35 per cent more milk and 61 per cent more butterfat than her dam.

A similar condition is found in the case of some of the daughters of the Jersey bull Pogis 80th of Hood Farm. The two cows 201 and 289 were full sisters, out of cow 13 and while cow 289 produced 26 per cent more fat than her dam cow 201 produced only 6 per cent more. Another pair of full sisters were cows 194 and 223 out of cow 127 and while cow 194 produced 54 per cent less fat than her dam, cow 223 produced 10 per cent more.

These facts clearly show that the factor of individuality is of exceedingly great importance in determining the production of an animal—in fact it is the greatest factor, others being only subsidiary. Two animals may be of the same "breeding" but of absolutely different powers so far as their "individual" producing ability is concerned. It must be admitted however that the greater the attention given to the selection of breeding stock for a number of generations the less will be the variation in producing ability of the individual animals of the same or similar breeding.

TABLE 5

The influence of individuality on production

SIRE	DAMS				DAUGHTERS				PERCENTAGE INCREASE IN PRODUCTION		
	Cow number	Average production			Cow number	Average production			Milk	Fat	Fat
		Milk	Fat	Fat		Milk	Fat	Fat			
		pounds	*pounds*	*per cent*		*pounds*	*pounds*	*per cent*	*pounds*	*pounds*	*per cent*
Guernsey											
Imp. Rouge II's Son	97	5288.9	229.42	4.33	247	8385.4	400.58	4.78	57	75	10
					286	8309.3	394.74	4.75	57	73	10
					322	8908.5	470.70	5.28	68	105	22
	98	7258.7	294.87	4.06	225	6213.0	294.16	4.73	−14	0	16
					267	9772.8	473.38	4.84	35	61	19
Jersey											
Pogis 80th of Hood Farm	13	8245.0	380.46	4.62	201	8735.2	401.55	4.60	6	6	0
					289	8345.5	479.30	5.74	1	26	24
	127	8190.5	382.92	4.68	194	3345.3	175.68	5.25	−59	−54	12
					223	7837.6	419.89	5.36	−4	10	15

"NICKING"

When animals are mated and the offspring resulting approaches the ideal which is being sought the animals mated are said to "nick" well. The problem of nicking is not given due consideration and in many cases a bull is discarded as useless because he did not give satisfactory results when mated to a certain group of cows, whereas, if he had been mated to other animals the results might have been excellent on account of the proper "nicking" taking place. This is well demonstrated in the case of the daughters of the Guernsey bull, Imp. Rouge II's Son.

At present records are available on 8 daughters of Imp. Rouge II's Son out of 5 cows and some good illustrations of the value of nicking can be found by dividing the daughters of this bull into two groups—those from cows producing less than 300 pounds of butterfat per year and those from cows producing more than this amount.

The two cows, 97 and 98, producing less than 300 pounds of butterfat per year had an average production of 264.27 pounds, while their 5 daughters—except No. 225 which just equalled her dam in fat production—exceeded their production by a considerable margin, the average increase being 47 per cent.

The three cows, 123, 186, and 187 produced on the average over 300 pounds of butterfat yet the daughters of these cows were in every case poorer than their dams, the average decrease being 10 per cent in butterfat yield.

If Imp. Rouge II's Son had been mated only to the cows in group II he would have been classed as of no value but his daughters out of the cows in group I were not only better producers than their dams but they were also better than the cows of group II. Consequently, it must be deduced that so far as milk and butterfat production were concerned Imp. Rouge II's Son did not nick well with the cows in group I. This fact must never be neglected in judging the merits of a bull for breeding purposes.

TABLE 6

"Nicking" as illustrated by the daughters of Imp. Rouge II's Son

GROUP	DAMS				DAUGHTERS				PERCENTAGE INCREASE IN PRODUCTION		
	Cow number	Average production			Cow number	Average production			Milk	Fat	Fat
		Milk	Fat	Fat		Milk	Fat	Fat			
		pounds	*pounds*	*per cent*		*pounds*	*pounds*	*per cent*	*pounds*	*pounds*	*per cent*
I	97	5288.9	229.42	4.33	247	8385.4	400.58	4.78	57	75	10
					286	8309.3	394.74	4.75	57	73	9
					322	8908.5	470.70	5.28	68	105	22
	98	7258.7	294.87	4.06	225	6213.0	294.16	4.73	−14	0	17
					267	9772.8	473.38	4.84	35	61	19
II	123	6326.9	322.22	5.09	292	5546.8	271.79	4.90	−12	−16	−4
	186	6854.9	312.41	4.56	254	5264.5	282.71	5.37	−23	−10	18
	187	8328.7	365.19	4.38	226	6650.3	335.46	5.04	−20	−8	15
Average group I		6305.5	264.27	4.19		8019.2	388.42	4.84	27	47	16
Average group II		7303.6	336.14	4.60		5875.3	301.62	5.14	−20	−10	12
Grand average		6331.0	286.98	4.53		7253.5	357.43	4.93	9	25	9

SUMMARY

1. Purebred dairy bulls vary greatly in their ability to transmit producing capacity to their offspring.

2. This is not a breed characteristic.

3. In determining the value of a bull the difficulties he has to overcome must be taken into consideration. When a bull is mated to high producing cows it is not always easy to have the next generation producing much better than their dams.

4. Animals of the same or similar breeding may vary greatly in producing ability due to individual characteristics.

5. Difficulty will sometimes be found in getting a bull that will "nick" properly with all the cows in a herd.

6. If the production of a herd is to be increased rigid selection on the basis of production must accompany intelligent breeding.

REFERENCES

(1) Eckles, C. H. 1911 Dairy cattle and milk production.

(2) Kildee, H. H., and McCandlish, A. C. 1916 Influence of environment and breeding in increasing dairy production. Bull. Ia. Agr. Expt. Sta. 165.

(3) Lawritson, M. N., Hendrickson, J. W., and Nevens, W. B. 1919 Purebred Sires Effect Herd Improvement. Cir. Neb. Agr. Expt. Sta. 8.

(4) McCandlish, A. C., Gillettee, L. S., and Kildee, H. H. 1919 Influence of environment and breeding in increasing dairy production. II. Bull. Ia. Agr. Expt. Sta. 188.

(5) Building up the dairy herds of Ohio. 1913 Cir. Oh. Agr. Expt. Sta. 135.

BACTERIAL CONTROL IN MILK PLANTS

RUSSELL S. SMITH

Department of Agriculture, Washington, D. C.

Milk inspectors and health officials should not rest assured of a safe product because of the mere presence of a milk pasteurizing plant in their city. Special attention must be given to the operation of such a plant in view of the fact that unless it is properly operated it may become a chance source of infection to the community.

In many instances, only an attempt at the process of pasteurization is being made. This is due to either a lack of proper attention and responsibility or to the absence of understanding, or the part of the operators, as to the functions and reasons for the process.

Bacteriological control of the process of pasteurization and of the condition of the subsequent containers and contact surfaces is essential. This examination should not be left entirely to the pasteurizing plant, but should be made frequently by competent officials under the direction of milk inspectors or health officials who are responsible for the condition of the milk supply and of the health of the community.

In considering the efficiency of various pasteurizing processes, it should be understood that the percentage reduction of bacteria in raw milk by heating does not form a measure of safeness of the final product. After heating, the so-called pasteurized milk is changed from its original condition and any inoculation subsequent to the heating introduces an uncertain element which may be of concern and which may void the reduction in bacteria already secured by heating the milk.

In the examination of milk to determine the percentage of reduction due to the heating process, a series of samples should be taken aseptically at intervals at the points representing definite stages in the pasteurizing process. It is only in this manner

that undue changes in the bacterial content can be noted and corrections made.

An accurate thermometer should be used to note the temperature at the various stages.

The first series of samples should be secured from raw milk entering the heating apparatus.

After the heating and holding process, in which temperature and time should be noted, another series of samples should be secured in the same manner at the point where the milk leaves the holder. This point of sampling varies with different apparatus and especially when the enclosed type of holder is used so that it is not always possible to secure samples immediately after the milk is held.

If milk is pumped, a series of samples should be secured before and after the pumping process.

Following the holding process, milk is usually run over a cooler and as it comes from the cooler, a series of samples should be secured and temperature noted.

The cooling process is usually followed by the bottling and a series of samples from the bottled milk should be secured and temperature noted.

In some plants the bottled milk is stored for a certain period in a refrigerator room prior to delivery. Sometimes this is an over-night storage and in such instances a series of samples of the held-over milk should be secured and the time of storage and temperature of the milk and the temperature of the storage room noted.

In general then we have the following points where a series of samples should be taken at intervals:

1. Raw milk at entrance to heater. (Temperature to be noted.)
2. Heated milk after being held. (Time and temperature to be noted.)
3. Milk as it comes from cooler. (Temperature to be noted.)
4. Milk in bottles or cans. (Temperature and time of delay before placed in storage to be noted.)

5. Milk in bottles or cans after storage. (Temperature of milk and air in storage room, and length of storage period to be noted.)

All samples should be iced and removed to the laboratory for dilution and plating as soon as possible. A chart showing the different stages where samples were secured can be made and the percentage reduction at each stage can be ascertained when the bacteria counts are known. A series of preferably five samples taken at intervals of several minutes at each point is essential in order that the true condition of the milk may be known throughout the process.

Using the average of the raw milk counts as a basis, the reduction at the various points can then be computed. A record of milk temperature, time of holding and of delays in handling, time of storage with temperature of storage room, are necessary for complete information.

It is also essential that a check be made on any automatic time and temperature controlling device that may be present. By immersing the recording thermometer bulb in the same liquid with an accurate tested hand thermometer for a period of time, a comparison can be secured. Any automatic time-holding device should be checked by comparing the time of holding with an accurate watch. Continuous holding apparatus can be checked by noting the time required to fill or to empty the holder. The length of holding sometimes depends on the capacity and speed of a milk pump, the speed being under control of a steam valve. By proper regulation of the speed of the milk pump, the time of holding may be controlled to some extent.

In the case of vat holders, the length of time the entire batch of milk is held at the pasteurizing temperature should be checked. When time is required for the vat to become filled and emptied, only the length of time the entire quantity of milk is held at the pasteurizing temperature should be considered. Recording thermometer charts usually record from the time the milk enters the vat and in the interpretation of the chart record, the time when the vat becomes filled should be known and the time

of holding the milk at the proper temperature gauged from that point to the time the vat starts to be emptied. This may result in some milk being held longer than the required time because of the time of emptying the vat, but it is the only positive way to insure the holding of all the milk at the proper temperature for the desired period of time.

INTERPRETATION OF RESULTS

The following table has been taken as an example for interpreting results from similar tests at many pasteurizing plants. The tests were made over a period of five days and are the averages of 128 samples.

Raw milk after clarifying:	
Temperature	84°
Count	152,375
Heated and held:	
Time	30 minutes
Temperature	145°
Count	6,240
Reduction	96 per cent
Off cooler:	
Temperature	45.2°
Count	8,452
Reduction	94.4 per cent
Bottled:	
Temperature	51°
Count	15,592
Reduction	89.7 per cent
Stored twenty-four hours:	
Temperature	42.2°
Count	24,386
Reduction	83 per cent

	TEMPERATURE	BACTERIA COUNT	PER CENT BACTERIA COUNT INCREASE
Increase due to milk passing over cooler...		2212	35.4
Increase due to milk passing through bottler...	5.8°	7140	83.4
Increase due to milk being stored twenty-four hours (*temperature decrease).....	*8.8°	8894	57.0

From the time of maximum reduction (96 per cent) to time the milk was in the bottle, reduction—89.7 per cent—there was a difference of 6.3 per cent in reduction. This represents a total increase in temperature of 5.8°, and a bacteria count increase of 9352 per cubic centimeter or 149.8 per cent.

From the time of maximum reduction (96 per cent) to the time of delivery, after twenty-four hours storage, reduction—83 per cent—there was a difference of 13 per cent in reduction. This represents a total decrease in temperature of 3° and a total increase in bacteria of 18,146 per cubic centimeter or 290.8 per cent.

The reason for the increases should be sought, as there is evidence of a waste of energy in allowing increases to occur after a certain degree of reduction has been gained.

Since the milk, after being reduced in bacterial content (96 per cent), has passed over the surface of a cooler, that is the first point where attention to cleanliness and sterilization should be centered. Exposed surfaces always allow access for dust particles and bacteria which may be adhering to the same. Improper washing and sterilization of pipes and cooler surfaces allow milk to collect and sour and dry in crevices and joints. Milk passing through or over such accumulations become inoculated. This is easily noted when the first milk over the cooler shows an excessive increase in bacterial content. A bacterial examination of sterile water run over the cooler prior to the milk-cooling operation will reveal the source of trouble.

PUMPS

If milk is pumped, the condition of the inside of the pump may cause inoculation of milk. Securing the bacterial condition of a series of milk samples secured before and after the pumping process, will determine the increase due to the agitation or inoculation caused by the pump. A bacterial examination of sterile water run through the pump when it is not in use may reveal a deposit of sour or dried milk which has become an inoculating agent.

BOTTLING MACHINE

The bottling machine in a milk plant is sometimes a difficult piece of equipment to clean properly. The rubber parts and filling mechanism should be taken apart and thoroughly cleaned after each day's run. If valves are not removed, an accumulation of drain-water occurs, and unless this is disposed of before the filling begins, the first bottles filled may show excessive bacterial counts as well as added water. Such a condition has been noted quite frequently and is due to carelessness. An instance has been noted of the use of a strong disinfectant, in an attempt to sterilize the bottling machine and the presence of the disinfectant in the first milk bottled and delivered to consumers. This shows the extent of carelessness that may be attained in this respect.

A bacterial examination of the drain-water or of sterile water run through the filling valves will help to determine the source of inoculation.

BOTTLES

Custom rules that the transparent glass bottle is the most common container for milk. Custom seems to also rule that it is the most misused container among the perishable food containers which are used for marketing purposes. Economy rules that the cost of a glass bottle requires it to be used over and over in order that its value may be realized.

It is a discouraging thing to know that sometimes when an empty milk bottle looks to be clean, in reality it is not. It is this deception which causes many bottles to be refilled with milk with no special attention being given to their washing and sterilization.

The washing and sterilization of returned empty milk bottles in a city milk plant has become a difficult and expensive problem. In order to secure the best results, there must be several inspections and then a final inspection for the detection of the visibly unclean bottles so that the business may not be injured by loss of trade or publicity because of unclean containers.

Returned bottles should be sorted before any attempt at washing is made. Those which contain visible dirt should go to the soaking machine for special attention, and those which are passed as washable should go to the rinsing, washing and steaming machines, which have quite recently been developed to a high degree of proficiency. The makers of bottle-washing machines do not claim that unwashable bottles can be made clean, neither do they insure the condition of the bottles after they leave the washing machine. Improper storage or handling may void the utmost previous precautions against inoculation.

Bacterial tests for the condition of the empty bottles which are to be filled, should be made frequently. The method employed usually consists of rinsing empty bottles with about 30 cc. of sterile water. Test tubes containing this quantity can be prepared in the laboratory and taken to the milk plant. Bottles ready to be filled are selected at random from the supply and the 30 cc. of sterile water poured in each. A milk bottle cap is then placed in each bottle and a thorough shaking given. Some of the rinse water from each is then drawn off into sterile test tubes and a bacteriological examination made of it in the laboratory. The total count of 1 cc. of the rinse water can be determined and then the bacterial condition of the bottle as affecting 1 cc. of milk poured therein, can be computed. While the inoculation per cubic centimeter of milk may in some instances be small, it must be remembered that the results show inoculation which may develop under favorable conditions with a detrimental effect on the milk.

The inoculation of the milk from the milk bottle itself can be reduced to a minimum by thorough washing, steaming and draining prior to filling. Such reduction of the chances of inoculation should be the object of milk plant operators and milk inspectors alike.

Under various conditions of washing and steaming of milk bottles at different milk plants, the inoculation per 1 cc. of milk that would come from bottles varied as the conditions varied. In order to show the effect of different methods, the following tables were prepared by differentiating between con-

ditions where good methods were in practice, and conditions other than good which were associated with high inoculation.

Bottle washing (no mechanical washer or steamer)

PLANTS	BOTTLES	AVERAGE INITIAL INOCULATION PER CUBIC CENTIMETER
9	30	2636.0
1	15	1192.4
1	20	568.0
1	10	395.0
7	90	167.0
1	25	78.1
20	190	Average 458.2

Range of initial bacterial inoculation, 0 to 9005.

Mechanical washer and steamer present

1	12	238.0
1	8	149.0
1	10	137.0
1	10	115.0
3	24	92.9
2	45	72.3
1	10	4.8
1	20	Less than 1
1	15	Less than 1
12	154	Average 78.8

Range of initial bacterial inoculation, less than 1 to 900.

Total plants..... 32
Total bottles..... 344
Average initial inoculations, all conditions..... 288.3
Difference of 82.8 per cent in favor of mechanical washer and steamer.

The illustration shows that when mechanical bottle washers and steamers were used and special attention paid to the inspection and storage after washing, that the average inoculation per cubic centimeter was 78.8, the range being from less than 1 to 900. When other than these conditions for washing were used, the results showed a higher average and a wider range.

Taking all conditions, good and poor, of washing and steaming bottles at city milk plants, as shown by the following table,

the average inoculation per cubic centimeter secured by examining 344 bottles at 32 plants, was 288.3, varying from less than 1 to 9005.

Under commercial conditions, it seems reasonable to expect the average bacterial inoculation of bottles to be confined within the average range secured when standard mechanical washers and steamers are in use, and care is given to storage prior to filling. Should the bacterial inoculation fall outside this average, it would be well to consider changes in methods and equipment, and to devote more attention to this part of the plant operation.

An experiment was conducted at one milk plant to determine to what extent if any, the bacterial condition of bottles would be changed by rinsing with cool water just prior to filling. In this instance, the rinsing was desired because of a faulty storage consisting of upright bottles and a warm room. The following table shows the results of the tests on a case of bottles half of which were tested before rinsing and the other half being tested after rinsing.

BEFORE RINSING		AFTER RINSING	
Total bottle count	Average initial inoculation per cubic centimeter milk	Total count	Average initial inoculation per cubic centimeter milk
120,000	240.0	16,000	3.2
3,840	7.5	5,200	6.4
15,200	31.0	2,000	4.0
31,200	62.4	4,800	9.6
44,400	88.0	6,600	13.6
42,928	85.8	3,720	7.4

Difference due to rinsing, 91.4 per cent.

While a reduction of 91.4 per cent was secured by the rinsing and a slight cooling of the bottle resulted, the operation may be called impractical in that it constitutes an added expense of water and of equipment and handling, as a substitute for correct storage by inverting bottles in a cool room. It also causes the handling of wet cases and bottles at the filling machine and

because of the rinsing, admits a chance for inoculation if the rinse water becomes contaminated.

CANS

The initial inoculation per cubic centimeter of milk which may be given when it is poured into a milk can should be a matter of concern. The inoculation thus acquired is governed by the condition and number of cans used in the transportation and sale of the product, and in many instances the degree of inoculation becomes sufficient to seriously injure or ruin the milk.

Since the milk can is the recognized last container which is used for transporting milk between the milk shipper and the city dairy, the responsibility of the condition of this container should be definitely fixed. Inoculation from cans varies from the efficiency of washing, steaming and drying and the length of time between the washing process and filling of cans with milk.

The proper apparatus to be used in efficient can washing seems to be a wash tank with rushing facilities, rinsing tank, steam jet and air blast. Accompanying this equipment, there must be a proper storage space. No system of handling the cans is complete unless the metal can covers and lids or wooden plugs receive a thorough washing and drying.

In the examination of milk cans under various washing and steaming conditions, it has been found that while some of the essential equipment was present, the entire operation was carried on so hurridly as to make the method ineffective.

The usual procedure in the bacterial examination of empty milk cans is to secure a sample of drain water in the can, if sufficient is present, otherwise 200 cc. of sterile water is poured into the can. After a thorough rinsing, a sample of the rinse water is secured by pipette, placed in a sterile test tube and removed to the laboratory for bacterial examination.* If the drain water is sampled, the count per cubic centimeter is multiplied by the quantity of the drain water to secure the total number of bacteria in the can. If the sterile rinse water (200 cc.), has been introduced into the can, the bacteria count of the sample should

be multiplied by 200 in order to secure the total number of bacteria in the can.

When the total bacteria per can is known, the number is divided by the volume of the can in cubic centimeters, in order to determine the probable initial inoculation per cubic centimeter that would result if the can were to be filled with milk or other liquid.

The following tests were carried on under three conditions classified as follows:

1. Cans delivered to railroad for shipment to producers from plants having wash tanks, washing powder, hand brushes, and steam jets for washing and steaming. The cans were both wet and dry inside.

2. Freshly washed cans at city milk plants having tanks, washing powder, hand brushes, and steam jets. All cans slightly moist.

3. Freshly washed cans at milk plants having mechanical washing machine and air blast for drying cans.

Condition 1

Cans from milk plants were tanks, hand brushes, cleansing powder, and steam jets were present. Examined at the railway station as they were being sent to shippers.

PLANTS	TOTAL CANS	CONDITION	AVERAGE INOCULATION	RANGE
29	146	Wet: 108	547,994	52 to 4,332,000
		Dry: 38	1,870	2 to 19,632

Inoculation in wet cans 99.7 per cent more than in dry cans.

In conjunction with the above conditions, it may be interesting to note the effect of a complete change of method and equipment such as was installed in one milk plant during the course of the investigations.

Bacteria counts were made on a series of 10 cans as they were delivered to the railroad, before the new apparatus was installed, as follows:

CANS	AVERAGE AMOUNT OF DRAIN IN CANS	AVERAGE INOCULATION PER CUBIC CENTIMETER	RANGE OF INOCULATION
	cc.		
9	83	88,500	23,700 to 178,000

After the can-washing machine with attached air blast was installed, bacteria counts were made on a series of 12 cans delivered to the railroad as follows:

CANS	CONDITION	AVERAGE INOCULATION PER CUBIC CENTIMETER	RANGE OF INOCULATION
12	5 dry 7 damp	122	52 to 634

Difference of 99.8 per cent in condition of cans delivered to the railroad for shipment, due to the installation of can-washer, steamer and dryer.

Condition 2

Freshly washed cans at city milk plants, just prior to filling or shipping back to producers. Tanks, hand brushes, cleansing powder and steam jets were present. All cans slightly moist inside.

PLANTS	TOTAL CANS	AVERAGE INITIAL INOCULATION
4	29	684.0
10	131	86.7
3	6	1564.0
1	11	196.7
6	30	162.0
1	16	20.7
1	11	205.8
1	10	18.7
27	244	Average 614.0

Range of initial bacterial inoculation, 5.2 to 2750.

In conjunction with the above conditions, it became possible to secure comparative tests when one milk plant installed a can steamer during the investigation.

Bacteria tests were conducted on a series of 10 freshly washed cans when no facilities for thorough steaming were present:

CANS	CONDITION	AVERAGE INITIAL INOCULATION PER CUBIC CENTIMETER	RANGE
10	Slightly moist	206.3	60 to 675

After a new can steamer was installed, a series of bacterial tests was made on 9 freshly washed cans as follows:

CANS	CONDITION	AVERAGE INITIAL INOCULATION PER CUBIC CENTIMETER	RANGE
9	Slightly moist	97.3	1.5 to 441

The series of tests showed a difference of 53 per cent in favor of the installation and use of a can steamer.

Condition 3

Freshly washed cans at milk plant. Washing machine and air blast used for washing and drying cans.

PLANTS	CANS	AVERAGE INITIAL INOCULATION PER CUBIC CENTIMETER	RANGE OF INOCULATION
2	10	18.6	0 to 62
1	34	9.7	0 to 331
1	16	20.2	1.3 to 91.5
4	60	Average 14.0	Range 0 to 331.0

From the foregoing conditions, it may be concluded that it is possible and thoroughly practicable to secure a comparatively low initial inoculation in milk cans when the proper apparatus is installed and in constant daily use.

MILK BOTTLE CAPS

The milk bottle cap may well be considered as a part of the final container of milk. While it may not be possible to measure the degree of inoculation given to milk by the bottle cap, it must not be overlooked as a source of inoculation.

The possibility of inoculating milk by introducing infectious disease germs from the fingers of persons inserting milk caps into bottles, must be recognized as a chance source of infection.

The use of machine cappers for inserting caps and the proper storage of the caps in sealed tubes, must be recommended as much more preferable than capping by hand. The bacterial condition of milk-bottle caps poorly stored in bulk lots and exposed to moisture, dust and flies has been compared with bottle caps properly stored in sealed tubes ready for the capping machine. While the initial inoculation is necessarily small because of the limited surface in contact with milk, nevertheless, a difference of 88.8 per cent in initial inoculation per cubic centimeter of milk in favor of caps in sealed tubes, was noted.

The usual method of procedure in determining the bacterial condition of milk bottle caps is as follows:

Secure a bunch of from 20 to 30 bottle caps as constituting a fair sample of those being used, taking care not to inoculate the surfaces. In the laboratory, the entire number of caps are placed in a sterile glass beaker.

Sterile water, 100 or 200 cc., is then poured over the caps and a sterile pipette or rod, used to separate and stir the contents for several minutes. A sample of the wash water is then drawn into a sterile pipette and an examination carried on the same as for bottle and can rinse water.

The total bacterial count per cubic centimeter is multiplied by the quantity of sterile water used, and the total count secured is then divided by the number of caps tested. This will give the approximate number of bacteria per cap, but as only one-half of the cap surface is exposed to the milk in the bottle, it is necessary to divide again by 2, to secure the approximate initial inoculation, resulting from the cap contact surface.

It is not uncommon to find the initial inoculation per cubic centimeter of milk ranging from 0 to 400 for each cap, but the usual limits, where care is taken in storage, may be found between 0 and 6.

CONCLUSION

Bacterial control of pasteurization and of the factors which may subsequently affect the milk, are essential to the industry. Laboratory facilities where bacterial tests may be conducted should be associated with every milk plant, because of the check that is thereby made possible on equipment and labor and on the quality of the product received and the product delivered.

The initial innoculation given to milk, resulting from the bacterial condition of exposed surfaces, coolers, bottling machines, pumps, pipes, milk bottles, milk cans, and bottle caps should be reduced to the minimum. This is only possible when strict daily attention is given to cleaning and sterilizing these contact surfaces.

The knowledge of the degree of development of bacteria under favorable conditions causes a realization that initial inoculation given to milk may ultimately spoil it, and from an economical standpoint, at least, precaution is of value.

Under proper conditions, it is possible and thoroughly practical on a commercial scale to secure in subsequent containers, a comparatively small range of initial inoculation. This is evidenced from the foregoing tests which are fairly indicative of common practices, as found during investigations, observations and bacterial examinations, personally made, in 92 milk plants located in 27 cities.

After a certain degree of reduction in bacteria content of milk has been secured by heating and holding for the specified time, it is poor business to allow the result to be made void or nearly so because of subsequent inoculation.

The process of pasteurization of milk and all of the factors which may influence the milk after it has been pasteurized should be under bacterial control, either by the milk-plant bacteriologist or an experienced bacteriologist employed by the city board of health, for it is only when control is present that desired results are obtained.

ABSTRACTS AND REVIEW OF DAIRY LITERATURE

THE YEASTS[1]

The relation of bacteria to disease probably accounts for the thoroughness with which they have been studied and the number of books which have been written upon bacteria and their activities.

The yeasts are uniformly present in dairy products and play an important part in practically all fermentations, including bread making, and still there is little available literature on yeasts. In fact until recently there has not been a satisfactory text book on this subject.

Appreciating the significance of the recent work of Dr. A. Guilliermond, Dr. F. W. Tanner has joined with this author in producing a new text. This text makes available the scattered information concerning the morphology and physiology of yeast, giving particular attention to their cytology, development, nutrition, reproduction and alcoholic fermentation. Additional chapters present the methods of cultivation, of characterization and of indentification, followed by chapters on classification and description of known species. The list of described species includes not only the true yeasts but extends into the doubtful yeasts and related fungi.

While it is known that yeasts are always present in fair numbers in dairy products little or nothing is known of the sources from which they enter nor the means best calculated to regulate their activities. Our ignorance in these matters is in considerable part due to the lack of a suitable text for training students to handle and study yeasts. This text will be found of great value in meeting this need.

H. A. HARDING.

[1] By A. Guillermond and F. W. Tanner. John Wiley and Sons, New York, 1920.

DAIRY NOTES

J. W. HENDRICKSON

Department of Dairy Husbandry, University of Nebraska, Lincoln, Nebraska

COLORADO

The following publications have been completed and sent out from the Dairy Department of the Colorado State College: Bulletin 202 "Testing and Handling of Milk and Cream" by R. McCann, and "Dairy Marketing Survey in Colorado" by J. A. Raitt.

The Station is at present working on the project, "Average Cost of Pasture for Dairy Cows," and when completed they expect to have data of considerable value to the dairymen of Colorado and adjacent states.

Men who were formerly connected with the dairy department of the Colorado State College are now located in the following positions:

R. McCann, National Dairy Council, Chicago, Ill.

E. B. Darrow, Corbett Ice Cream Company, Denver, Colo.

H. J. Haakenson, Fieldman, Boulder Creamery, Denver, Colo.

E. Baker, Colorado Milk Producers Association, Denver, Colo.

D. S. Jordan, Agricultural Professor, Monte Vista, Colo.

Mr. C. N. Shepardson is a member of the Department staff in the position of assistant professor of dairying.

MASSACHUSETTS

The following changes have taken place in the department during the past year:

Prof. O. A. Jamison resigned his position as associate professor of dairying to take up commercial work as manager of the Attleboro Milk Producers Company, Attleboro, Mass.

Mr. Fred E. Wheeler resigned from his position as instructor of dairying, April 10, 1920 and is now connected with the Milk Producers Dairy Company of Pittsfield, Mass.

Mr. D. L. James gave up the position of extension specialist in dairying, May 22, 1920 in order to become manager of the Fall River Milk Producers Corporation.

Mr. S. E. Van Horn is also connected with the Fall River Milk Producers Corporation since leaving his position as buttermaker in the department.

The following new men have come into the department during the past year: Mr. H. F. Judkins as assistant professor of dairying, November 6, 1919; Mr. T. G. Yaxis, assistant professor of dairying, December 27, 1919; Mr. Glen E. Upton, instructor of dairying, appointed April 28, 1920, and Mr. Adelbert Sheffield took the place of Mr. Van Horn in August 1, 1920. Mr. H. F. Pendleton has recently been placed on the department staff as instructor of dairying.

NEW JERSEY

The Dairy Department of the New Jersey Experiment Station is working on a project in coöperation with the United States Dairy Division. This project involves a comparison of line-breeding to out-crossing and of in-breeding to out-crossing. Jerseys are being used for the in-breeding work and Holsteins for the line-breeding in this experiment. A second generation of in-bred animals are now available in the New Jersey herd.

Mr. John Hill, assistant dairy husbandman, resigned July 1, 1920, to go into commercial work. His place is being taken by Mr. S. W. Mead who recently completed his work for Masters Degree at Minnesota.

Mr. Stanley B. Roberts has recently been added to the faculty as assistant dairy specialist.

Mr. W. B. Combs, formerly a member of the New Jersey Dairy Department is now professor of dairying at Pennsylvania Agricultural College.

Mr. L. S. Reford, who formerly occupied a similar position is now at Auburn, N. Y. in commercial work.

TEXAS

Mr. J. W. Ridgway resigned as head of the Dairy Husbandry Department June 1, in order to take up work as County Agent of Cooke County, Texas with headquarters at Gainsville.

Mr. R. L. Pou was appointed professor of dairy husbandry, July 1, 1920.

Prof. J. A. Clutter came into the College Station Dairy department during the last year.

The most recent change in the department staff is the addition of Mr. A. L. Darnell, as associate professor of dairying, the appointment being effective September 1, 1920.

CHANGES IN UNITED STATES DAIRY DIVISION PERSONNEL

Resignations

G. L. Oliver, dairy husbandman, in charge of dairy extension work in the Middle West, has purchased a farm near Richmond, Va., where he plans to put into practice his knowledge of dairying.

C. L. Walp, scientific assistant in dairying, who was employed as office assistant in the dairy farming section, has resigned to go as a partner with Mr. Oliver on his farm near Richmond.

J. H. McClain, who has been in charge of southern dairy extension work for twelve years, has resigned to manage his own dairy farm at Campobello, South Carolina.

O. A. Storvick, dairy manufacturing specialist, engaged in creamery investigations, has resigned to accept a position as Western Representative for the Gude Brothers Kieffer Company.

W. M. Clark, dairy chemist, who has been employed on the chemical investigations in connection with the ripening of Swiss cheese, has resigned to accept a position with the Public Health Service.

W. G. McGowan, agent in dairying, engaged in coöperative dairy extension work in Mississippi, has resigned to accept a position in dairy extension work in the State of Virginia.

W. E. Tomson, dairy husbandman, engaged in coöperative dairy extension work in the State of Montana, has resigned to accept a position with the University of California.

Earle Brintnall, agent in dairying, engaged in coöperative dairy extension work in North Carolina, has resigned to accept a position in dairy extension work in the State of Mississippi.

H. J. Childress, agent in dairying, engaged in coöperative dairy extension work in the State of Oklahoma, has resigned to accept the position of county agent in the State of Kentucky.

W. E. Peterson, agent in dairying, engaged in coöperative dairy extension work in the State of Kansas, has resigned to accept a position with the Minnesota Holstein-Friesian Breeders' Association.

Appointments

J. A. Conover, dairy extension worker in this Division 1906–1911, and superintendent of the Naval Academy Dairy, 1911–1920, has been appointed for the organization of bull associations.

Alan Leighton, who received his B.S. degree from New Hampshire State College, and has taken graduate work in Cornell University, has been appointed as physical chemist in the Dairy Division laboratories, by transfer from the Bureau of Mines.

E. L. Westover, who served as coöperative dairy extension worker in the State of Oregon since May 1, 1917, has resigned to do extension work for the American Guernsey Cattle Club.

Lee Coe, coöperative extension cheese worker in North Carolina, died of appendicitis, at Boone, North Carolina, September 15, 1920. Mr. Coe was an expert cheesemaker in New York State previous to his appointment in the Dairy Division, March 1, 1918.

INDEX TO VOLUME III

ABSTRACTS and reviews of dairy literature, 430, 555
Acidity of fresh milk, 227
Acidity of milk, development of, 52
Agriculture investigation, organization of, 169
ALLEN, E. W. Organization of investigation in agriculture, 169
American Dairy Science Association, Committee appointments for 1920, 236
American Dairy Science Association, proceedings of, 1919, 61

BACTERIA in milk and how their numbers may be reduced, 308
Bacterial control in milk plants, 540
Bacteriological and biochemical study of experimental butter, 375
Biochemical and bacteriological study of experimental butter, 375
Bitterness in evaporated milk, 486
Bromthymol blue test, bromcresol purple test, and methylene blue reduction test, relative value of, in determining the keeping quality of milk, 353
Bromcresol purple test, bromthymol blue test, and the methylene blue reduction test, relative value in determining the keeping qualities of milk, 353
BROWN, CHAS. W., SMITH, LULU M., and RUEHLE, G. L. A. A bacteriological and biochemical study of experimental butters, 375
B. subtilis and Strept. lacticus in milk, an associative study of, 406
Bulls, A study in, 529
Butter, creamery, A study of the incorporation of proteins in, 452
Butter, determination of fat in, a comparison of the decantation method with other methods for, 425
Butters, experimental, a bacteriological and biochemical study of, 375
Butter fat content and total solids content of creams of varying richness separated from the same sample of milk, 522
Butter, fishy flavor in, 194
Butter, mottles in, their causes and prevention, 77
"Buttons" in sweetened condensed milk, their cause and control, 122

CALF-FEEDING, Efficiency of milk substitutes in, 315
CARR, R. H., and SPITZER, GEO. The efficiency of milk substitutes in calf feeding, 315
Cause and control of "buttons" in sweetened condensed milk, 122
CHAMBERS, W. H., PRUCHA, M. J., HARDING, H. A., and WEETER, H. M. How do bacteria get into milk at the farm and how may their numbers be reduced, 308
Clarification of milk, 245
Colorimetric hydrogen ion determination, The keeping quality of milk as judged by the, 156
Committee appointments for the American Dairy Science Association for 1920, 236
Condensed milk, "buttons" in, their cause and control, 122
Condensed milk, sweetened, factors influencing the viscosity of, 468
Conformation and its relation to milk producing capacity in Jersey cattle, 1
COOLEDGE, L. H., and WYANT, R. W. The keeping quality of milk as judged by the colorimetric hydrogen ion determination, 156
CORDES, W. A., and HAMMER, B. W. An unusual outbreak of ropy milk, 291

Corn cannery refuse, digestibility of, 370
Corn silage in concrete and stave silos, A comparative study of, 300
Correction for volume of precipitate in the polarimetric determination of lactose in milk, 134
Cost of milk production and milk prices, 180
CUSICK, J. T. Fishy flavor in butter, 194

DAHLBERG, A. O., EVANS, ALICE C., and ROGERS, L. A. The cause and control of "buttons" in sweetened condensed milk, 122
Dairy cattle, The eleventh annual students' national contest in judging, 206
Dairy literature abstracts and reviews, 430, 555
Dairy Notes, 239, 431, 556
Dam, age of, Relation to fecundity in domesticated animals, 260
DAVENPORT, AUDREY, AND HASTINGS, E. G., The effect of pasteurization on the number of bacteria in milk when this is determined by the direct microscopic count, 494
DAVENPORT, AUDREY, and HASTINGS, E. G. The relative value of the methylene blue reduction test, the bromthymol test, and the bromcresol purple test in determining the keeping quality of milk, 353
Decantation method, A comparison of, with other methods for the determination of fat in butter, 425
DEYSHER, E. F., EVANS, F. R., ROGERS, L. A., Factors influencing the viscosity of sweetened condensed milk, 468
Digestibility of corn cannery refuse, 370
Digestibility of sorghum mill refuse, 367

ELEVENTH annual student's national contest in judging dairy cattle, 206
EPPLE, W. F., and SPITZER, GEORGE. Bitterness in evaporated milk, 486
EVANS, ALICE C., ROGERS, L. A., and DAHLBERG, A. O. The cause and control of "buttons" in sweetened condensed milk, 122
EVANS, F. R., ROGERS, L. A., DEYSHER, E. F., Factors influencing the viscosity of sweetened condensed milk, 468
Experiments with and practical application of heat sterilization for all parts of milking machines, 33

FABIAN, F. W. A score card for city ice cream plants, 230
Fecundity in domesticated animals, The relation of age of dam to, 260
Fermented milk and milk diets in controlling intestinal putrefaction, 414
FISHER, R. C. The use of fermented milk and milk diets in controlling intestinal putrefaction, 414
Fishy flavor in butter, 194

GOWEN, JOHN W. Conformation and its relation to milk producing capacity in Jersey cattle, 1

HAECKER and SAVAGE feeding standards for dairy cattle, Modification of, 190
HAMMER, B. W., and CORDES, W. A. An unusual out break of ropy milk, 291
HARDING, H. A. Abstracts and reviews of dairy literature, 430, 555
HARDING, H. A., and PRUCHA, M. J. Is ropy milk becoming more serious trouble, 502
HARDING, H. A., and PRUCHA, M. J. Suggestions regarding the control of municipal milk supplies, 107

HARDING, H. A., WEETER, H. M., CHAMBERS, W. H., and PRUCHA, M. J. How do bacteria get into milk at the farm and how may their number be reduced, 308

HART, GEO. H., and STABLER, W. H. Experiments with and practical application of heat sterilization for all parts of milking machines, 33

HASTINGS, E. G., and DAVENPORT, AUDREY. The effect of pasteurization on the number of bacteria in milk when this is determined by the direct microscopic count, 494

HASTINGS, E. G., and DAVENPORT, AUDREY. The relative value of the methylene blue reduction test, the bromthymol blue test, and the bromcresol purple test in determining the keeping quality of milk, 353

Heat sterilization for all parts of milking machines, Experiments with and practical application of, 33

HEINEMAN, P. G. Orla-Jensen's classification of lactic acid bacteria, 143

HENDRICKSON, J. W. Dairy Notes, 239, 431, 556

HOOD, E. G., and MARSHALL, CHARLES E. Clarification of milk, 245.

HOSMAN, D. FAY, and HUNZIKER, O. F. Mottles in butter—their causes and prevention, 77

HUNZIKER, O. F., and HOSMAN, D. FAY. Mottles in butter—their causes and prevention, 77

ICE cream and other frozen products, proportioning the ingredients for, 439

Ice cream, score card for city plants, 230

Investigation in agriculture, Organization of, 169

JENSEN'S, Orla, Classification of lactic acid bacteria, 143

Jersey cattle, Conformation and its relation to milk producing capacity in, 1

JONES, SARAH V. H., and ROUSE, JAMES E. The relation of age of dam to observed fecundity in domesticated animals. I. Multiple births in cattle and sheep, 260

KEEPING quality of milk as judged by the calorimetric hydrogen ion determination, 156

LACTIC acid bacteria, Orla-Jensen's classification of, 143

Lactose in milk, Correction for volume of precipitate in the polarimetric determination of, 134

LEVINE, C. O. The water-buffalo as a dairy animal, 340

McCANDLISH, ANDREW C. A modification of the Haecker and Savage feeding standards for dairy cattle, 190

McCANDLISH, ANDREW C. A study in bulls, 529

McCANDLISH, ANDREW C. The digestibility of sorghum mill refuse, 367

McCANDLISH, ANDREW C. The digestibility of corn cannery refuse, 370

McINERNEY, T. J. A note on the acidity of fresh milk, 227

McINERNEY, T. J. A preliminary report on the study of the temperatures at which milk of different per cents of acidity will coagulate, 220

MARSHALL, CHARLES E., and HOOD, E. G. Clarification of milk, 245

MARSHALL, MAX S. An associative study of Strept. lacticus and B. subtilis in milk, 406

Methylene blue reduction test, the bromthymol blue test, and the bromcresol purple test, relative value of in determining the keeping quality of milk, 353

Microscopic count, direct, the effect of pasteurization on the number of bacteria when this is determined by, 494

Milk, Clarification of, 245
Milk, development of acidity of, 52
Milk diets and fermented milk, use of in controlling intestinal putrefaction, 414
Milk, evaporated, Bitterness in, 486
Milk, fresh, Acidity of, 227
Milk prices and cost of milk production, 180
Milk—keeping quality of, as judged by the colorimetric hydrogen ion determination, 156
Milk, keeping quality, tests, 353
Milk plants, Bacterial control in, 540
Milk producing capacity and its relation to conformation in jersey cattle, 1
Milk production, Cost of and milk prices, 180
Milk, ropy, An unusual outbreak of, 291
Milk, ropy, Is it becoming a more serious dairy trouble, 502
Milk substitutes, Efficiency of in calf-feeding, 315
Milk supplies, Municipal, suggestions regarding the control of, 107
Milking machines, Heat sterilization for all parts of, 33
Modification of the Haecker and Savage feeding standards for dairy cattle, 190
Mottles in butter—Their causes and prevention, 77
Multiple births in cattle and sheep, 260
Municipal milk supplies, Suggestions regarding the control of, 107

NORTON, R. B., and SHAW, R. H. A comparative study of corn silage in concrete and stave silos, 300
Notes, Dairy, 239, 431, 556

OKIMOTO, SAICHI, and OVERMAN, O. R. A comparison of the decantation method and other methods for the determination of fat in butter, 425
Organization of investigation in agriculture, 169
Orla-Jensen's classification of lactic acid bacteria, 143
OVERMAN, O. R., and OKIMOTO, SAICHI. A comparison of the decantation method with other methods for the determination of fat in butter, 425
OVERMAN, O. R., and STIRITZ, B. A. A comparison of the butterfat content and the total solids content of creams of varying richness separated from the same sample of milk, 522

PASTEURIZATION, The effect of, on the number of bacteria in milk when this is determined by the direct microscopic count, 494
PEARSON, F. A. Milk prices and cost of milk production, 180
PERKINS, A. E. Correction for volume of precipitate in the polarimetric determination of lactose in milk, 134
Polarimetric determination of lactose in milk, correction for volume of precipitate in, 134
Proceedings of American Dairy Science Association, 1919, 61
Proteins in creamery butter, A study of the incorporation of, 452
PRUCHA, M. J., and HARDING, H. A Is ropy milk becoming more serious trouble, 502
PRUCHA, M. J., and HARDING, H. A. Suggestions regarding the control of municipal milk supplies, 107
PRUCHA, M. J., HARDING, H. A., WEETER, H. M., and CHAMBERS, W. H. How do bacteria get into milk at the farm and how may their number be reduced, 308

RABILD, HELMER. The eleventh annual students' national contest in judging dairy cattle, 206
Report on the study of the temperatures at which milk of different per cents of acidity will coagulate, 220

Reviews and abstracts of dairy literature, 430, 555

ROGERS, L. A., DAHLBERG, A. O., and EVANS, ALICE C. The cause and control of "buttons" in sweetened condensed milk, 122

ROGERS, L. A., DEYSHER, E. F., EVANS, F. R., Factors influencing the viscosity of sweetened condensed milk, 468

Ropy milk, An unusual out break of, 291

Ropy milk, Is it becoming a more serious dairy trouble, 502

ROUSE, JAMES E., and JONES, SARAH V. H. The relation of age of dam to observed fecundity in domesticated animals. I. Multiple births in cattle and sheep, 260

RUEHLE, G. L. A., BROWN, CHAS W., and SMITH, LULU M. A bacteriological and biochemical study of experimental butters, 375

SCORE card for city ice cream plants, 230

SHAW, R. H., and NORTON, R. P. A comparative study of corn silage in concrete and stave silos, 300

Silos, concrete and stave, A comparative study of corn silage in, 300

SMITH, LULU M., RUEHLE, G. L. A., and BROWN, CHAS. W. A bacteriological and biochemical study of experimental butters, 375

SMITH, RUSSELL S., Bacterial control in milk plants, 540

SPITZER, GEO., and CARR, R. H. The efficiency of milk substitutes in calf feeding, 315

SPITZER, GEORGE, and EPPLE, W. F., Bitterness in evaporated milk, 486

Sorghum mill refuse, Digestibility of, 367

STABLER, W. H., and HART, GEO. H. Experiments with and practical application of heat sterilization for all parts of milking machines, 33

Sterilization for all parts of milking machines, Experiments with and practical application of heat, 33

STEUART, D. W. The development of acidity of milk, 52

STIRITZ, B. A., and OVERMAN, O. R. A comparison of the butterfat content and the total solids content of creams of varying richness separated from the same sample of milk, 522

Strept. lacticus and B. subtilis in milk, an associative study of, 406

Students national contest in judging dairy cattle, 206

Suggestions regarding the control of municipal milk supplies, 107

TEMPERATURES at which milk of different per cents of acidity will coagulate, 220

Total solids and butterfat content of creams of varying richness separated from the same sample of milk, 522

VISCOSITY of sweetened condensed milk, factors influencing the, 468

WATER buffalo as a dairy animal, 340

WEETER, H. M., CHAMBERS, W. H., PRUCHA, M. J., and HARDING, H. A. How do bacteria get into milk at the farm and how may their number be reduced, 308

WILLIAMS, O. E. Proportioning the ingredients for ice cream and other frozen products, 439

WYANT, R. W. A study of the incorporation of proteins in creamery butter, 452

WYANT, R. W., and COOLEDGE, L. H. The keeping quality of milk as judged by the colorimetric hydrogen ion determination, 156

JOURNAL
OF
DAIRY SCIENCE

VOLUME III
JANUARY, 1920, to NOVEMBER, 1920

1920
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

COPYRIGHT 1921 BY
WILLIAMS AND WILKINS COMPANY

EDITORIAL BOARD

J. H. FRANDSEN, *Editor-in-Chief*
Lincoln, Nebraska

BOARD OF EDITORS

A. C. ANDERSON
Lansing, Mich.
F. W. BOUSKA
Chicago, Ill.
C. H. ECKLES
St. Paul, Minn.
E. S. GUTHRIE
Ithaca, N. Y.
H. A. HARDING
Urbana, Ill.
O. F. HUNZIKER
Chicago, Ill.
H. H. KILDEE
Ames, Iowa
C. LARSEN
Brookings, S. D.
C. W. LARSON
Dairy Div. Dept. Agr.
Washington, D. C.
W. P. B. LOCKWOOD
Amherst, Mass.
M. MORTENSEN
Ames, Iowa
LEROY S. PALMER
Columbia, Mo.
FRED RASMUSSEN
State College, Pa.
B. H. RAWL
Washington, D. C.
C. L. ROADHOUSE
Davis, Calif.
L. A. ROGERS
Washington, D. C.
W. A. STOCKING, JR.
Ithaca, N. Y.
M. R. TOLSTRUP
Henderson, Minn.
H. E. VAN NORMAN
Davis, Calif.
R. M. WASHBURN
St. Paul, Minn.
IVAN C. WELD
Washington, D. C.
G. C. WHITE
Storrs, Conn.
W. B. NEVENS
Lincoln, Nebr.

All correspondence regarding articles should be directed to J. H. Frandsen, Editor-in-Chief, Lincoln, Nebraska.

All correspondence regarding advertising should be directed to the Publishers, Williams & Wilkins Company, Baltimore, Md.

CONTENTS

JANUARY. No. 1

Conformation and Its Relation to Milk Producing Capacity in Jersey Cattle. John W. Gowen 1
Experiments With and Practical Application of Heat Sterilization for All Parts of Milking Machines. George H. Hart and William H. Stabler... 33
The Development of Acidity in Milk. Dan W. Steuart 52
Proceedings of American Dairy Science Association—1919 61

MARCH. No. 2

Mottles in Butter—Their Causes and Prevention. O. F. Hunziker and D. Fay Hosman 77
Suggestions Regarding the Control of Municipal Milk Supplies. H. A. Harding and M. J. Prucha 107
The Cause and Control of "Buttons" in Sweetened Condensed Milk. L. A. Rogers, A. O. Dahlberg and Alice C. Evans 122
Correction for Volume of Precipitate in the Polarimetric Determination of Lactose in Milk. A. E. Perkins 134
Orla-Jensen's Classification of Lactic Acid Bacteria. P. G. Heineman 143
The Keeping Quality of Milk as Judged by the Colorimetric Hydrogen Ion Determination. L. H. Cooledge and R. W. Wyant 156

MAY. No. 3

Organization of Investigation in Agriculture. E. W. Allen 169
Milk Prices and Cost of Milk Production. F. A. Pearson 180
A Modification of the Haecker and Savage Feeding Standards for Dairy Cattle. Andrew C. McCandlish 190
Fishy Flavor in Butter. J. T. Cusick 194
The Eleventh Annual Students' National Contest in Judging Dairy Cattle. Helmer Rabild 206
A Preliminary Report on the Study of the Temperature at which Milk of Different per cents of Acidity Will Coagulate. T. J. McInerney 220
A Note on the Acidity of Fresh Milk. T. J. McInerney 227
A Score Card for City Ice Cream Plants. F. W. Fabian 230
Committee Appointments for the American Dairy Science Association for 1920 236
Dairy Notes. J. W. Hendrickson 239

JULY. No. 4

Clarification of Milk. Charles E. Marshall and E. G. Hood 245
The Relation of Age of Dam to Observed Fecundity in Domesticated Animals. I. Multiple Births in Cattle and Sheep. Sarah V. H. Jones and James E. Rouse 260

An Unusual Outbreak of Ropy Milk. B. W. Hammer and W. A. Cordes... 291
A Comparative Study of Corn Silage in Concrete and Stave Silos. R. H. Shaw and R. P. Norton... 300
How Do Bacteria Get Into Milk at the Farm and How May Their Number be Reduced? M. J. Prucha, H. A. Harding, H. M. Weeter and W. H. Chambers... 308

SEPTEMBER. No. 5

The Efficiency of Milk Substitutes in Calf Feeding. Geo. Spitzer and R. H. Carr... 315
The Water Buffalo as a Dairy Animal. C. O. Levine... 340
The Relative Value of the Methylene Blue Reduction Test, the Bromthymol Blue Test, and the Bromcresol Purple Test in Determining the Keeping Quality of Milk. E. G. Hastings and Audrey Davenport... 353
The Digestibility of Sorghum Mill Refuse. Andrew C. McCandlish... 367
The Digestibility of Corn Cannery Refuse. Andrew C. McCandlish... 370
A Bacteriological and Biochemical Study of Experimental Butters. Chas. W. Brown, Lulu M. Smith and G. L. A. Ruehle... 375
An Associative Study of Strept. lacticus and B. subtilis in Milk. Max S. Marshall... 406
The Use of Fermented Milk and Milk Diets in Controlling Intestinal Putrefaction. R. C. Fisher... 414
A Comparison of the Decantation Method with Other Methods for the Determination of Fat in Butter. O. R. Overman and Saichi Okimoto.. 425
Abstracts and Reviews of Dairy Literature. H. A. Harding... 430
Dairy Notes. J. W. Hendrickson... 431

NOVEMBER. No. 6

Proportioning the Ingredients for Ice Cream and other Frozen Products. O. E. Williams... 439
A Study of the Incorporation of Proteins in Creamery Butter. R. W. Wyant 452
Factors Influencing the Viscosity of Sweetened Condensed Milk. L. A. Rogers, E. F. Deysher and F. R. Evans... 468
Bitterness in Evaporated Milk. George Spitzer and W. F. Epple... 486
The Effect of Pasteurization on the Number of Bacteria in Milk When this is Determined by the Direct Microscopic Count. E. G. Hastings and Audrey Davenport... 494
Is Ropy Milk Becoming a More Serious Dairy Trouble. H. A. Harding and M. J. Prucha... 502
A Comparison of the Butterfat Content and the Total Solids Content of Creams of Varying Richness Separated from the Same Sample of Milk. B. A. Stiritz and O. R. Overman... 522
A Study in Bulls. Andrew C. McCandlish... 529
Bacterial Control in Milk Plants. Russell S. Smith... 540
Abstracts and Review of Dairy Literature. H. A. Harding... 555
Dairy Notes. J. W. Hendrickson... 556
Index... 561

This MARK OF SUPERIORITY will be found on all equipment for the

CITY MILK PLANT
ICE CREAM PLANT
and the CREAMERY

that is manufactured by

J. G. CHERRY COMPANY

These well known Dairies are using Cherry Pasteurizing equipment—all or in part:

GEO. M. OYSTER CO., Washington, D. C.
CARRY MFG. CO., Washington, D. C.
FARMERS DAIRY CO., Toronto, Canada
EDMONTON CITY DAIRY, Edmonton, Canada
POLK SANT. MILK CO., Indianapolis, Ind.
UNION DAIRY CO., St. Louis, Mo.

You will be interested in the particulars of the Cherry Method of Pasteurization. Ask us!

J.G.CHERRY COMPANY

ST. PAUL MINN. — TAMA IOWA — PEORIA ILL
CEDAR RAPIDS
IOWA

DIRECTORY SECTION

EAGLE "MIKADO" PENCIL No. 174

Regular Length, 7 inches

For Sale at your Dealer. Made in five grades

Conceded to be the Finest Pencil made for general use.

EAGLE PENCIL COMPANY, NEW YORK

The

Marschall Dairy Laboratory

Madison, Wisconsin

RENNET EXTRACT — CHEESE COLOR

THE QUALITY OF THE MARSCHALL RENNET-COLOR HAS NEVER BEEN EQUALLED

The largest and only up-to-date factory in America devoted exclusively to the production of Pure Rennet Extract and Cheese Color.

Chr. Hansen's Laboratories, Inc.

LITTLE FALLS, N. Y.

are headquarters for the genuine and well-known CHR. HANSEN'S DANISH RENNET EXTRACT; also PEPSIN EXTRACT

CHEESE COLOR and BUTTER COLOR

LACTIC FERMENT CULTURE

BUTTERMILK TABLETS and BULGARIAN MILK CULTURE

RENNET TABLETS for Cheese Making on the farm

CHEESE COLOR TABLETS and the world-famous JUNKET PREPARATIONS

INTERNATIONAL CENTRIFUGES

INTERNATIONAL EQUIPMENT COMPANY

352 Western Ave. (Brighton)

BOSTON, MASS.

Catalog Cy. on request

Back Volumes

OF THE

Journal of Dairy Science

Vols. I and II, six issues to each volume, may be purchased:

Price, net postpaid:
$11.00, United States, Mexico, Cuba
$11.50, Canada
$12.00, other countries.

Williams and Wilkins Company

Publishers Baltimore, U. S. A.

[Just Published]

For Chemists, Metallurgists, Biologists, and Bacteriologists

The Determination of Hydrogen Ions

by

W. Mansfield Clark, Ph.D.

This treatise on the hydrogen electrode, indicator, and supplementary methods of determining hydrogen ion concentrations, with an indexed bibliography of eleven hundred references on applications, is an important contribution to the literature in this field.

Are You Interested in

analytical methods, in the acidity of your garden soil, in enzymes, in blood and the determination of acidosis, in modern methods of handling protein solutions, in the cultivation and study of bacteria, yeasts, molds and tissue, in autolysis, hydrogen ion catalyses, colloids, the digestive system, filtration, plant distribution, natural waters, the hydrogen ion concentration of biological fluids?

If so, you will need the methods and the references found in

The Determination of Hydrogen Ions

Limited Edition **318 pages**

NUMEROUS ILLUSTRATIONS **INDICATOR CHART IN COLORS**

WILLIAMS & WILKINS COMPANY, Publishers

WILLIAMS AND WILKINS COMPANY,
Mount Royal and Guilford Avenues,
Baltimore, U. S. A.

Please enter an order for.....copy(s) of The Determination of Hydrogen Ions by W. Mansfield Clark, Ph.D. Remittance for $5.00, United States, Mexico, Cuba; $5.25, Canada; $5.50, other countries, is enclosed to cover. (or) Remittance will be made on receipt of your statement. (or) Remittance will be made about.....1921.

Name .....
(Please state whether Dr., Prof., etc.)

Address .....

SOIL SCIENCE

Published Monthly. **Two volumes (1000 pages) a year are issued.** **Illustrated.**

PRICES

	U. S. and Dependencies	Canada	Other Countries
CURRENT VOLUMES, 1920, Vols. IX and X.....	$6.00	$6.25	$6.50
BACK VOLUMES, 1916-1919, incl., Vols. I-VIII, incl.....	24.00	25.00	26.00

Williams & Wilkins Company

Publishers :: :: :: Baltimore, U. S. A.

CAMBRIDGE UNIVERSITY PRESS
Fetter Lane, London

BEUTELSPACHER Y CIA
Sarmiento 815, Buenos Aires

MARUZEN AND CO.
Nihonbashi Tori-Sanchome, Tokyo

1920 # Abstracts of Bacteriology **Volume IV**

Comprising complete reviews and abstracts of American and foreign work in Bacteriology, Mycology and Protozoology in their relation to the arts and sciences

Under the editorial direction of the
SOCIETY OF AMERICAN BACTERIOLOGISTS

EDITOR
A. PARKER HITCHENS

Published bi-monthly. One volume a year at present. About 500 pages to a volume

Price, net postpaid: $5.00, United States, Mexico, Cuba;
$5.25, Canada; $5.50, other countries

Subscriptions are received for the volume only. Single copies are not sold

Back Volumes, Vols. I, II, and III. Price, net postpaid: $18.00,
United States, Mexico, Cuba; $18.75, Canada; $19.50, other countries

---

Subscription Order for the Abstracts of Bacteriology

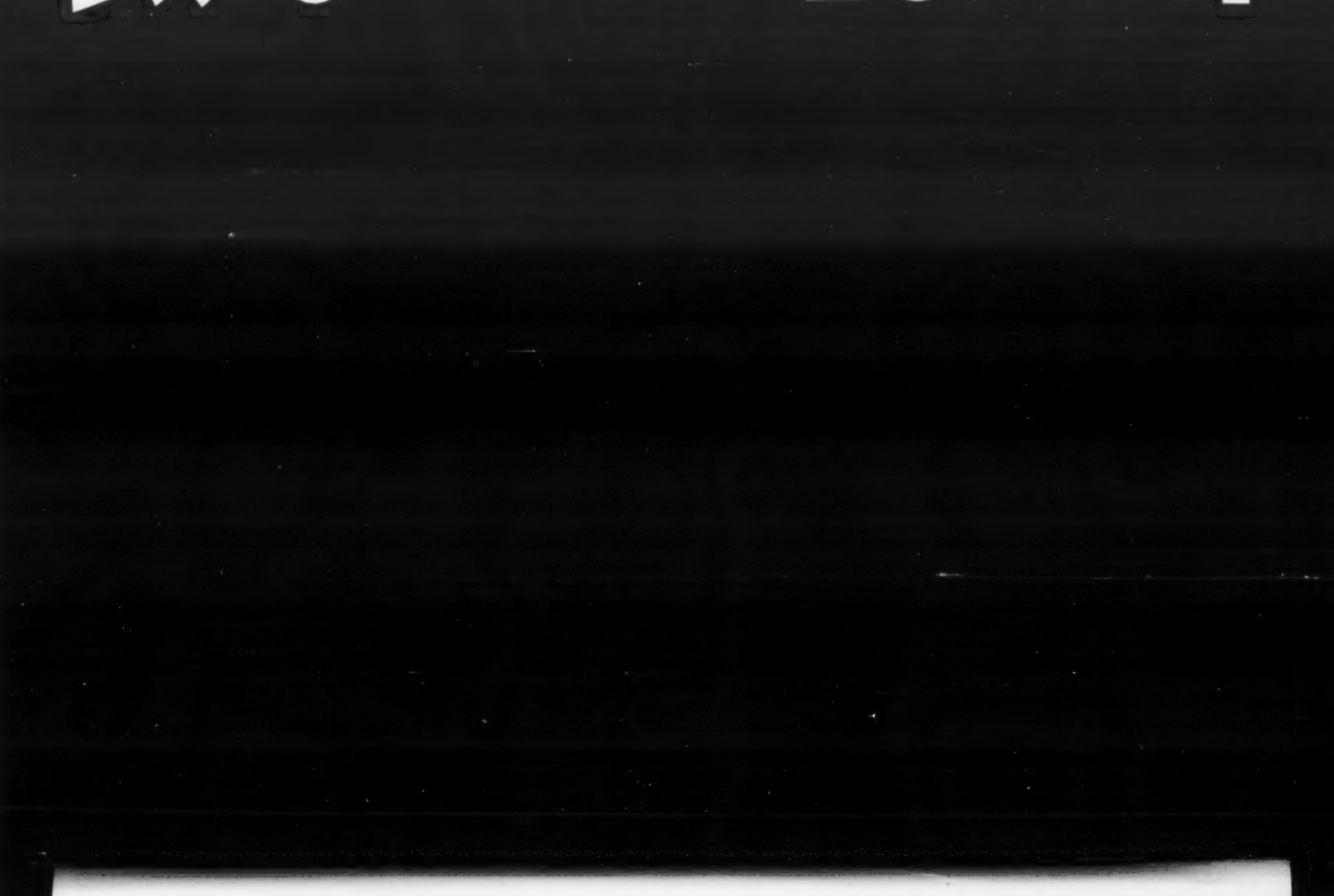
WILLIAMS & WILKINS COMPANY
MOUNT ROYAL AND GUILFORD AVENUES,
BALTIMORE, MD., U. S. A.

_____ 19____

I / We } enclose { $5.00 (U. S.-Canada) / $5.50 (foreign) } for subscription to the present volume of ABSTRACTS OF BACTERIOLOGY.

Name _____
(Please state whether Dr., Prof., etc.)

Address _____



AFRS-D8

YOUR SUBSCRIPTION EXPIRES
with this issue

YOUR RENEWAL
SHOULD BE GIVEN PROMPT ATTENTION
if it has not been sent in

NOTE: The subscriptions of members of the American Dairy Science Association will be handled through the Secretary of the Association.

Renewal Order for
JOURNAL OF DAIRY SCIENCE

1921 Volume: Vol. IV: $5.00, United States, Mexico, Cuba; $5.25, Canada; $5.50, elsewhere. Prices are net, postpaid.

.....19....

WILLIAMS & WILKINS COMPANY

Publishers of Scientific Journals and Books

BALTIMORE, MD., U. S. A.

I (We) wish to avoid any interruption in my (our) subscription to Journal of Dairy Science. Please continue it for Volume IV, January–December, incl., 1921, 6 issues.

I (We) { enclose check (money order) herewith. / have sent in renewal. / will remit ..... (Insert date)

Name.....

Address.....

Subscriptions are also received at the following addresses:

For Argentina and Uruguay: Beutelspacher y Cia., Sarmiento 815, Buenos Aires.

For Australia: Stirling & Co., 317 Collins Street, Melbourne.

For Belgium: Henri Lamertin, 58 Rue Coudenberg, Bruxelles.

For the British Empire, except Australia and Canada: Send to any British bookseller or agent, or forward direct to the Publishers.

For Canada: Wm. Dawson & Sons, Ltd., 87 Queen Street East, Toronto.

For Denmark: H. Hagerup's Boghandel, Gothersgade 30, Kjöbenhavn.

For France: Emile Bougault, 48 Rue des Ecoles, Paris.

For Germany: R. Friedländer & Sohn, Buchhandlung, Carlstrasse 11, Berlin NW. 6.

For Holland: Scheltema & Holkema, Rokin 74–76, Amsterdam.

For Italy: Ulrico Hoepli, Milano.

For Japan and Korea: Maruzen Company, Ltd. (Maruzen-Kabushiki-Kaisha), 11 to 16 Nibonbashi Tori-Sanchome, Tokyo; Fukuoka, Osaka, Kyoto, and Sendai, Japan.

For Spain: Ruiz Hermanos, Plaza de Santa Ana, 13, Madrid.

For Switzerland: Georg & Cie, Freistrasse 10, Basel.

THE USE OF

Nafis Testing Glassware

will reduce breakage in your testing room to a minimum.

For greatest strength there is no argument about the value of proper distribution of glass in the bodies of test bottles and proper annealing in order to withstand the strain of the centrifugal motion in the tester.

S6950 Test Bottle

Nafis Improved Dividers

Nafis Curved Point Pipette

NAFIS Test Bottles, Pipettes and other apparatus are made of the best quality of glass and are properly annealed. They are tested and graduated with the utmost care according to scientific principles.

Since LOUIS F. NAFIS, Inc., make only SCIENTIFIC GLASSWARE FOR TESTING MILK AND ITS PRODUCTS it is evident, in order to maintain the well established reputation for high grade glassware, that all the testing apparatus would be carefully made since it is guaranteed for its

Accuracy and Quality

If your dealer does not stock NAFIS GLASSWARE write for our catalog and list of distributors.

Louis F. Nafis, Inc.

Manufacturers of Scientific Glassware

542-548 Washington Blvd. **CHICAGO, U. S. A.**

AS NECESSARY AS SALT

Make good butter—
Protect its goodness—
Put your brand on it—

Get your butter to the consumer as fresh, pure and clean as when it leaves your churn. Protect it from dust and dirt by wrapping it in

PATERSON PIONEER PARCHMENT PAPER

and put your name on the parchment. That will mean a bigger demand for your butter and higher prices.

Write for free book "Better Butter."
Every dairyman should read it.

The Paterson Parchment Paper Co.
37 8th Street, Passaic, N. J.

THE DAIRY LABORATORIES

20th and Market Streets, Philadelphia, Penna.

CONSULTING AND ANALYTICAL CHEMISTS

Complete Chemical and Bacteriological Analysis of Milk, Ice Cream, Dairy Products, Food, and Water

Manufacturers of

"Special colored Corrosive Sublimate Tablets for preserving Composite samples in Babcock fat Testing"
"Chlorine Solution to sterilize milk utensils"
"Sour milk Testing Solution for detecting sour milk rapidly"
"Cultures for ripening milk in making buttermilk, butter, sour cream, etc."
"FLY Spray to keep flies off dairy cattle"

Sanitary Advice and Expert Assistance — All Tests Confidential

DR. LEE H. P. MAYNARD, Milk Expert — H. C. CAMPBELL, B.S., M.D., Ph.G., Chemist
DR. H. S. JOHNSON, Bacteriologist — RALPH FORT, Assistant

Branches at

WASHINGTON, D. C. — PITTSBURGH, PA.
BALTIMORE, MD. — ST. LOUIS, MO.